UNIVERSITY OF CALIFORNIA PUBLICATIONS

COLLEGE OF AGRICULTURE

AGRICULTURAL EXPERIMENT STATION

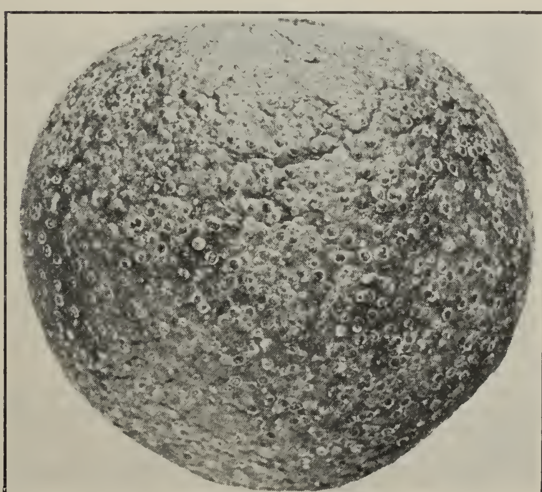
BERKELEY, CALIFORNIA

THE RED OR ORANGE SCALE

By H. J. QUAYLE

BULLETIN No. 222

(Berkeley, Cal., July, 1911)



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THE RED OR ORANGE SCALE.

Chrysomphalus aurantii Mask.

By H. J. Quayle.

HISTORICAL.

Chrysomphalus aurantii was first described from New Zealand by W. M. Maskell in 1878. The specimens described were found infesting oranges and lemons imported into New Zealand from Sydney. Two years later Professor Comstock observed a scale infesting orange groves at San Gabriel and Los Angeles, California. At first these were described by Comstock as a new species, but after receiving copies of Maskell's papers, giving the description of *Chrysomphalus aurantii*, and upon receiving specimens from New Zealand, he concluded that they were the same as those occurring there.

Regarding the occurrence of the scale in this state in 1880 Comstock says, "I have observed this species in several groves at San Gabriel and Los Angeles. At the first named place, where it is very abundant, it is said to have first appeared on a budded orange tree which was purchased by Mr. L. J. Rose, at one of the hothouses in San Francisco. At Los Angeles it appears to have spread from six lemon trees which were brought from Australia by Don Mateo Keller. Thus the question as to the source from which we derived this pest is settled beyond a doubt."

While it is undoubtedly true that this scale was imported into this state directly from Australia, its native home can apparently be traced further back than our acquaintance with it there. It is now supposed that China is the native home of the red scale, though this is not positively established. The San Jose scale, *Aspidiotus perniciosus* was supposed for a long while to have had its origin in Chile or Australia, but later investigations showed that it had been introduced into both of these countries, and it was not until an exploration was made of the Orient that Marlatt[1] finally decided that China is its native habitat. So in the case of the red scale, it appears to have been introduced into Australia, and that it existed for centuries before in some of the Oriential countries. That China is the native home of the San Jose scale is further borne out by its relationships and distribution as an insect of temperate regions. But in the case of the red, the relationships and distribution are that of a tropical or semi-tropical insect rather than one of temperate regions.

Maskell N. Z. Trans. XI, p. 199 (1878).
Can. Ent. XIII, p. 8 (1881).
U. S. D. A. Rep., p. 294 (1880).
[1]Marlatt Bulletin 62, Bur. Ent. U. S. D. A., p. 10 (1906).

FIG. 1.—Map showing distribution of Red Scale over world.

DISTRIBUTION.

Over World. The red or orange scale is very widely distributed over the world, as shown by the accompanying map. It will be noticed that it is largely a tropical or semi-tropical insect. New Zealand represents the most southern location with a south latitude of 45° and New York the most northern point with a latitude of 45° north. But the red scale is not a pest in New York, and we are not sure but that this is simply a greenhouse or incidental locality. While it occurs in New Zealand at a latitude of 45° south there is here really a semi-tropical climate, for

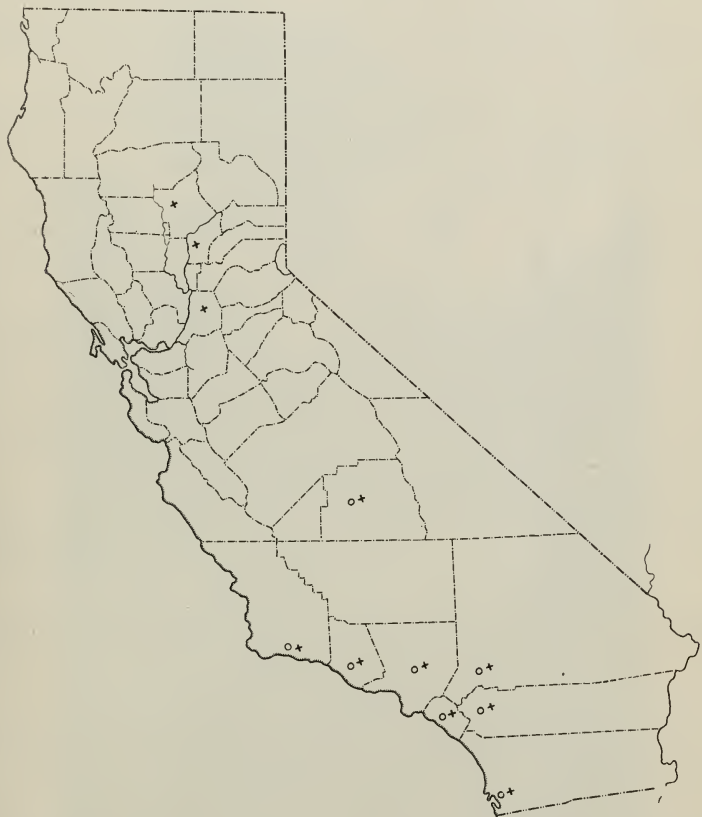

FIG. 2.—Map indicating distribution of Red and Yellow Scales in principal citrus fruit areas of California. o represents *C. aurantii;* x represents *C. aurantii* var. *citrinus.*

citrus trees are grown. According to Dewar[1], this scale is the most important citrus fruit pest in the Orange River Colony. In West Australia it is also considered the most serious scale of citrus trees. It also occurs as a citrus pest in Cape Colony and other localities where citrus fruits are grown.

[1]Ann. Rep. Ent. Orange River Colony.

The following places are recorded as having the red scale: Mauritius, Ceylon, India, S. Europe, Syria, Natal, Cape Colony, China, Japan, Australia, New Zealand, Java, New Caledonia, Samoa, Fiji, West Indies, Greece, Turkey, Italy, Spain, Singapore, New York, Ohio, Florida, and California.

In California. While the red scale is recorded from many other food plants than citrus trees, in this state it is limited as a pest entirely to the citrus, so that its distribution is governed largely by this host plant. In the citrus area south of the Tehachapi, this scale occurs in the following counties: Santa Barbara, Ventura, Orange, Los Angeles, Riverside, San

FIG. 3.—Map showing distribution of Red Scale over southern California citrus belt.

Bernardino, and San Diego. In Tulare County it occurs on citrus trees in the city of Visalia, but has not yet reached the commercial citrus section of that county around Porterville, Lindsay, and Exeter. It has been noted in abundance on orange and ivy at Selma in the San Joaquin Valley. It does not occur, so far as known, in Butte County, the citrus section of the Sacramento Valley. Here its place is occupied by the variety *citrinus*.

ECONOMIC IMPORTANCE.

The red scale is the second most important insect enemy of citrus trees in California. In fact, a good deal of evidence may be submitted for its claim to first place. If the yellow is included, which is justifiable,

since it is only a variety of the red, the total amount of control work directed against these would nearly, if not quite, equal that against its competitor for first place, the black scale. The black is more generally distributed, and has first place in most, if not all, of the coast counties. In the case of other scales occurring with the black, the black is usually considered as the least important when it comes to fumigating, since they are, if in the proper stage, more readily killed. For this reason the

FIG. 4.—Tree partially killed by Red Scale.

black is sunk into second place, whereas, if left untreated, would probably cause more injury than the one which the treatment was especially directed against.

The red scale ranks first as a citrus pest in Riverside and San Bernardino counties, two of the great citrus producing counties of the state. It also holds second place in Los Angeles and Orange counties, two other

counties where the citrus industry is of first importance. In San Bernardino County about $200,000 is spent annually for fumigation and $10,000 more for spraying to control citrus fruit pests. In Riverside County $75,000 is spent annually in fumigation and $8,000 in spraying for the same pests. While all of this is not directed against the red scale, the majority of it is, since in these two counties the red is the most injurious pest.

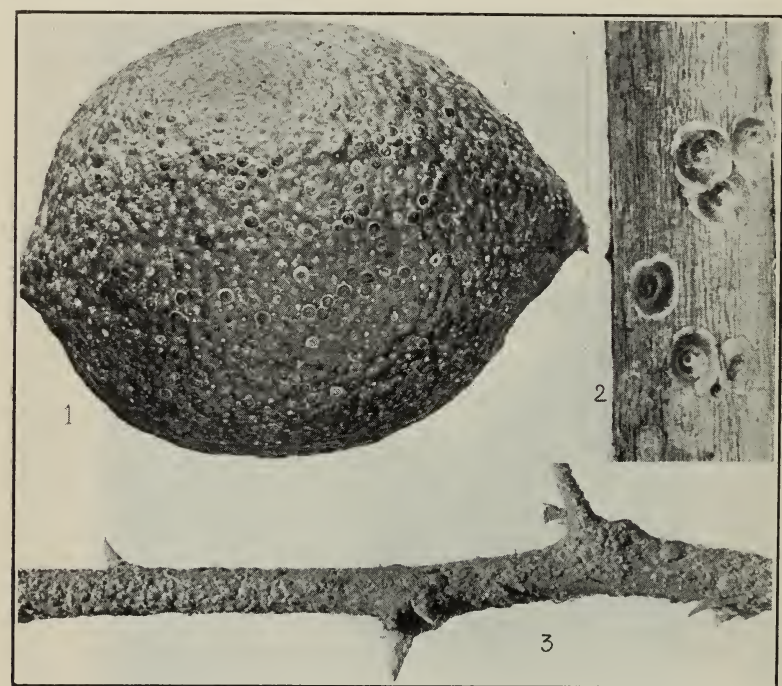

FIG. 5.—1 Red Scale on lemon. 2 Red Scale on nightshade. 3 Red Scale on twig of lemon.

No citrus scale in California so quickly and so permanently injures the tree as the red scale. The black seldom, if ever, kills a tree, its chief injury being due to the sooty mold fungus on the fruit. The purple often kills but a few of the lower or interior branches. But practically the entire tree may be killed by the red, sometimes in one or two years' infestation. It infests all parts of the tree, leaves, branches, fruit. It not only causes a dropping of the leaves, but actually kills large branches. Aside from this permanent and serious injury to the tree, the presence of the scale on the fruit renders it unmarketable. Trees that do not have a severe infestation of the scale, and where the tree itself is not seriously injured, may have its fruit badly infested by the scale.

No honey dew is given off by the red scale, so that the characteristic injury by the sooty mold fungus, as occurs with the unarmored scales, is not present in the case of the red. The injury is due directly to the feeding of the scales themselves, and, aside from their feeding, the fruit is marred simply by their presence.

The injury by feeding is due to the loss of chlorophyl, toxic effect on the tissues of the plant, and interference with the functions of the stomata when the scale is abundant. Some scales have a much more virulent poisoning effect on the tissues than others. One of the most marked in this respect is the San Jose scale *Aspidiotus perniciosus* Comst. On the fruit of apple or pear it causes a distinct reddening of the surface tissue. If the bark be cut off where this insect is present the deeper tissues will be seen to have a blackish red color. With such insects the presence of a few will noticeably injure the tree. In the case of others, such as the Greedy scale, *Aspidiotus rapax* Comst., the tree may be completely incrusted with them, yet the tree suffers no noticeable injury. It is only necessary to notice infestations of this scale on acacia, laurel and others to see how abundant they may become and still the tree appears normal. There is, to be sure, some injury done here, but it must be largely on account of loss of sap, and where the tree has plenty of moisture it can withstand a considerable drain in this respect. If the same number of San Jose scales were to infest a tree as often occurs with the *rapax* on acacia, laurel and others, the tree would be entirely killed. So with the red on the orange, a heavy infestation on the twigs and branches, as well as on the leaves and fruit, means the destruction of the tree.

FOOD PLANTS.

While the list of food plants of the red or orange scale is large, it is restricted very largely as a pest, to citrus trees. It is recorded from a number of deciduous fruit trees, but is not a serious pest on those trees. Most of the other food plants are ornamental, and pests on such plants never rank in importance with those on commercial fruit trees. Here in California the red scale is practically unknown away from the orange or lemon. It does, of course, get on to several different kinds of plants. but from an economic standpoint it is of little consequence excepting on the citrus. It frequently happens that other trees, near by citrus trees badly infested with this scale, will be infested to a greater or less degree; but it is not often that such trees or plants are permanently infested, and they seldom become serious enough to warrant treatment. The problem of controlling the red scale, then, is limited practically to citrus trees. In this respect the black scale presents a different situation. Outside the citrus groves, three very important host plants, olive, ole-

ander, and pepper occur abundantly and everywhere in southern California. One of the food plants, aside from the citrus, that is important from a control standpoint is the nightshade *Solanum douglassii.* This weed occurs in waste places and also among the trees in the grove; but the presence of this plant in a grove usually means neglect in cultivation or care of the trees. These plants, growing as they do under and among the trees, may be a source of reinfestation after fumigation. The castor bean is another common native plant attacked, but it is not generally in such close proximity to citrus trees.

The complete list of food plants from which the red scale has been recorded is as follows: orange, lemon, cocoanut, fig, olive, agave, plum, lignum vitæ, buxus, Euonymus, Pistacia, rose, pear, quince, apple, willow, oak, grape, acacia, tea plant, Podocarpus, wattle, Ligustrum, Artocarpus, sago palm, nightshade, English walnut, eucalyptus, camphor tree, Kennedya, passion flower, fuchsia, Bidens, Solidago, date palm, California palm.

DESCRIPTION OF THE STAGES.

First Larval Stage. Length .24 mm. Greatest width .15 mm. Color sulfur yellow. The pygidium has two central lobes well developed and conspicuous. Arising from each of these on the inner and dorsal sides is a spine .25 mm. long; also a small spine on outer basal margin. The median lobes are similar in shape to those of the adult female, that is, they are abruptly narrowed at about one half their length. There is but a slight indication of a second pair and the third is not present at all. There are two plates between the two median lobes and also two between the first and second. Beyond the second lobe are from three to four short plates. The antennæ consist of four indistinct segments of the following comparative lengths 4—2—2—14. The fourth is conspicuously annulate. There are six spines arising from the sides of this segment and two at the extreme tip. The tarsi have a single claw, and there arises from the end of the tibia and extending to or beyond the tip of the claw three of four nobbed hairs.

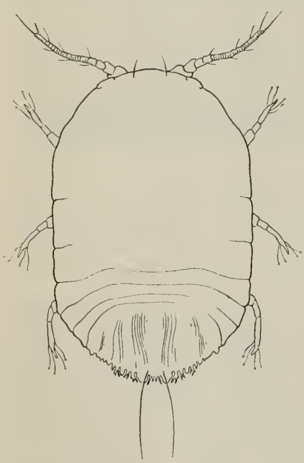

FIG. 6.—Motile young of Red Scale. x175.

Second Stage Female. After the first molt the scale increases to about twice its original size, and now all the characters of the pygidium are distinct, but the legs and antennæ are lost. There are three pairs

of conspicuous lobes with a spine arising from the base of each. Between the two median lobes and between those and the second are two conspicuous plates and three between the second and third lobes. Beyond this are three additional plates. All the plates are deeply fringed. There are no spinnerets.

The Adult Female. The average dimensions are about .78 mm. wide and 1 mm. long. The lateral margins of the body extend downward often as far as or beyond the tip of the pygidium.

The pygidium presents the following characters: There are three pairs of conspicuous lobes, each notched at about one half their length, making the distal half narrower than the basal. On the dorsal surface there is a spine accompanying each lobe. Those of the first pair are long and slender and situated at the outer basal margin, so placed that they may move either to the ventral or dorsal side of the lobes. On the other lobes there is one shorter and more blunt spine arising from the middle of the base of the lobe. On the ventral surface the first pair of lobes have the same spines, mentioned above in connection with the dorsal surface. On the other lobes are each a single spine situated in the middle at the base of the lobe corresponding to those above. There are two plates between the first pair of lobes, two between the first and second, two between the second and third and three beyond the third lobe. The first plate beyond the second lobe and the three beyond the third are deeply bifurcated and fringed on the lateral margin.

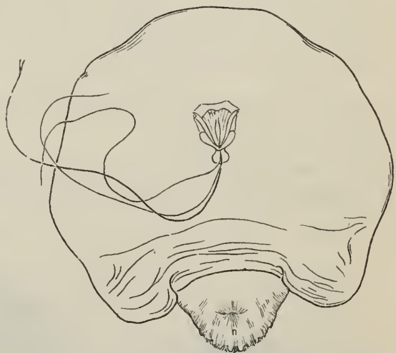

FIG. 7.—Ventral view of Red Scale. x50.

The dorsal surface of the pygidium shows a number of dorsal tubular spinnerets and several marginal spinnerets, as shown in the figure. It will be seen from this that they are not arranged uniformly on both sides of the median line. Near the upper margin are five curious shaped structures with a couple of blunt pointed prominences projecting anteriorly. On the ventral surface the vaginal cleft is shown, see figure, with its radiating lines. The tubular spinnerets may be faintly seen from this surface by focusing downward.

The Second Stage Male. There are no distinguishable differences between the sexes until after the first molt. After the first molt the male becomes more elongate or pyriform, as indicated by the following measurements: average length .7 mm., average width .4 mm. The

pygidium characters are the same as in the second stage female. There are two pairs of conspicuous purple eyes, one pair on the lateral anterior margin, while the other pair is more dorsal and are nearer together. Small spines arise from around the lateral margin.

The male propupa is orange yellow in color with the eyes very dark red or brown. Length .7 mm., greatest width .35 mm. Dorsal eyes are just posterior to antennal sheaths and in hollow formed by them. The ventral eyes are larger and closer together and a little more posterior than the dorsal. The sheaths of the antennæ and wings are visible, and a faint indication of those of the legs. But they are all more rudimentary and lie closer to the body than is the case in the next stage. There is no style present, but in its place is a blunt protuberance from which arise two distinct spines. The truncate posterior end with the button at the tip is the most evident character distinguishing this stage from the true pupa.

The male pupa is of the same general color as the propupa. Length exclusive of the style is .7 mm. The style is .1 mm. Greatest width .32 mm. The ventral eyes are large and almost touching each other.

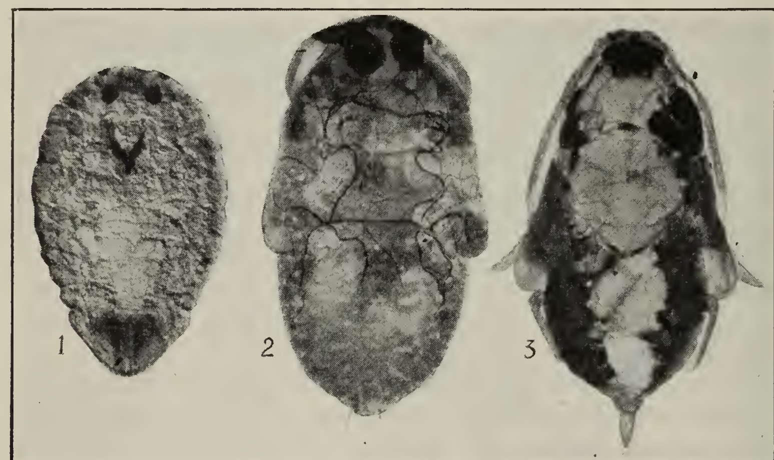

FIG. 8.—Stages of the male of the Red Scale. 1 Second stage. x56. 2 Propupa. x70. 3 Pupa. x70.

They are situated a short distance from the anterior margin. The dorsal pair of eyes are wider apart and somewhat closer to the anterior margin. The sheaths of the antennæ wings and legs are evident and ordinarily lie close to the body along the ventral margin.

The adult male has a wing expanse of 1.5 mm.; length exclusive of the style .6; style .22; color orange yellow; antennæ 10 jointed, the first two segments being much shorter and thicker than the others. The com-

parative lengths beginning with the proximal one are as follows: 5—4—17—20—20—20—18—15—13—17. Total length .5 mm. The antennæ are light colored with some yellow pigment. On all the joints excepting the first two are rather long hairs. The lateral pair of eyes are dark brown and situated just lateral of the antennæ. The ventral pair of eyes are much larger and closer together and situated more posteriorly. The legs, excepting coxæ which are yellow, are glassy white, and the tarsi light brown. The thoracic band is of a light brown color. The halteres are club-shaped, with the slender hook arising from the tip of the club.

FIG. 9.—Male of Red Scale. x40.

LIFE HISTORY AND HABITS.

THE ACTIVE LARVA.

The red scale is viviparous, hence the starting point in the life history is with the active larva, which are born alive. This means that what ordinarily corresponds with the egg hatches within the body of the parent, instead of the embryo developing and the eggs hatching outside the body of the parent. Very rarely there appears an object that looks very much like an egg. There are no free appendages or other characters common to the young insect. But if this is placed under a microscope or examined closely with a lens it will be seen that there is a perfectly developed young insect within which is surrounded by an enveloping membrane—the amnion. This encloses the developing larva, and ordinarily is cast off within the oviduct, but occasionally, as intimated, this is not cast off until it is outside the oviduct. The larva emerging from beneath the parent scale, where it may have remained for a day or two after birth, crawls about for a day or two longer before settling and becoming fixed. It is most usual to find them settling on the following day, but if, in the mean time, a suitable place for becoming stationary and obtaining food is not found, they may remain active for a day or two longer. They do not as a rule migrate very far from their parent scale. Several oranges, badly infested with red scale which were producing young, were each placed in a young orange tree that was entirely free from scale. Two or three weeks later those trees were examined to determine if any had settled on the tree. Hundreds of young scales with their white circular covering were found, and imme-

diately about the fruit for a few inches the branches and leaves were simply peppered with young scales. As the distance from the point of liberation increased the number of scales decreased, and the maximum distance they were found to travel and become fixed was 19 inches above on one tree and 21 inches below on another. The tree was succulent and thrifty and offered suitable ground for settling without much crawling about. In other cases they are, of course, likely to go farther, and, in addition to their own powers of traveling, they may be distributed about by other insects. A fuller discussion of the subject of locomotion is given under the head of "Locomotion and Spread."

Temperature and humidity records covering period when most of the life history data on Chrysomphalus aurantii were secured.

	Humidity (means).			Temperature.	
	7 A. M.	12 M.	5 P. M.	Mean minimum.	Mean maximum.
1909—February	91	65	80	44	73.2
March	84.4	62	74.9	45.6	76
April	83.4	56	69	50.7	80.1
May	83	57.7	66.5	53	81.3
June	83.5	63.4	65.9	57.1	84.2
July	85.4	59.9	68	59	87.1
August	82.6	50.1	59.1	57.2	93.1
September	85.4	56.1	72.5	58.9	90.8
October	83.1	55.2	75.5	52.8	84
November	83.1	58	78	45.9	75.8
December	81.6	74.9	80.6	44	73

SETTLING OF THE LARVÆ.

A few larvæ will settle down on the same day of emergence, but the great majority will be found to settle on the following day. Daily records of emergence were made on about 1000 scales, and out of this number they would be occasionally found to settle before examination on the following day. Records kept on 884 young larvæ liberated in leaf cages showed that about 95 per cent settled within one day. But here the larvæ were picked from infested fruit as they were actively crawling about, so that some may have been emerged for some time.

The proportion settling and becoming established in our cages was 41 per cent. These were liberated on leaves and had practically normal conditions. The fact that they were enclosed in cages and thus protected from enemies or becoming dislodged and falling to the ground, was really in favor of a greater number becoming fixed than would be the case were they out in the open. The insects were transferred by a small camel's hair brush or a needle. Possibly some may have been injured in the transfer, but care was taken in this regard, and usually the count of the number liberated was made of those actually crawling about and unharmed in the cages.

The following table shows the number that settle, and, since these experiments were extended over several months of the year, there appears to be little effect due to season:

Date.	Number Liberated	Number Settled	Date.	Number Liberated	Number Settled
1908—September 21	10	4	1909—September 22	20	11
September 23	20	5	September 22	15	5
September 23	20	11	September 30	3	2
September 23	15	5	October 1	12	9
November 24	13	6	October 1	7	5
1909—January 30	14	5	October 4	5	5
June 19	30	14	October 5	12	12
June 19	30	13	October 11	8	5
July 2	25	6	October 11	13	4
July 2	25	8	October 11	12	6
July 2	25	8	October 13	11	5
July 3	30	10	October 14	5	4
July 21	20	7	October 20	9	4
July 24	20	5	October 20	6	3
August 12	9	4	October 21	6	2
August 13	20	5	November 26	12	5
August 18	14	11	1910—May 31	10	4
August 18	14	10	May 31	10	2
August 18	6	2	May 31	10	4
August 21	7	4	June 3	10	5
September 2	14	6	June 6	10	4
September 2	10	6	June 6	10	3
September 3	14	9	June 17	10	2
September 3	14	4	June 17	25	6
September 4	6	3	June 20	7	2
September 4	15	6	June 20	9	6
September 7	18	5	June 20	11	4
September 7	20	5	June 20	12	6
September 22	15	7	June 20	11	2
September 22	18	7			
September 22	18	8	Total	884	363
September 22	20	13			
September 22	16	8	Per cent settled, 41.06.		

They may settle either on the leaves, branches or fruit. It seems to make no very great difference where they settle so long as it is convenient. But the part of the tree that is more likely to be severely infested first is the branches, later the leaves, and finally the fruit. They will be found on both sides of the leaves, but the upper side, usually, has the greater numbers. In the case of the yellow it is more often the under side. The red will not settle readily on the older and larger corky branches, but prefer the younger succulent branches where not so much of the corky material has been deposited.

FORMATION OF THE SCALE COVERING.

When the active larva first settles the legs and antennæ are withdrawn beneath the body and in an hour or two a cottony secretion appears from numerous pores over the body. In another hour a light flimsy covering of cottony threads envelops the entire scale and extends down over the sides of the insect to the surface on which it is resting. The

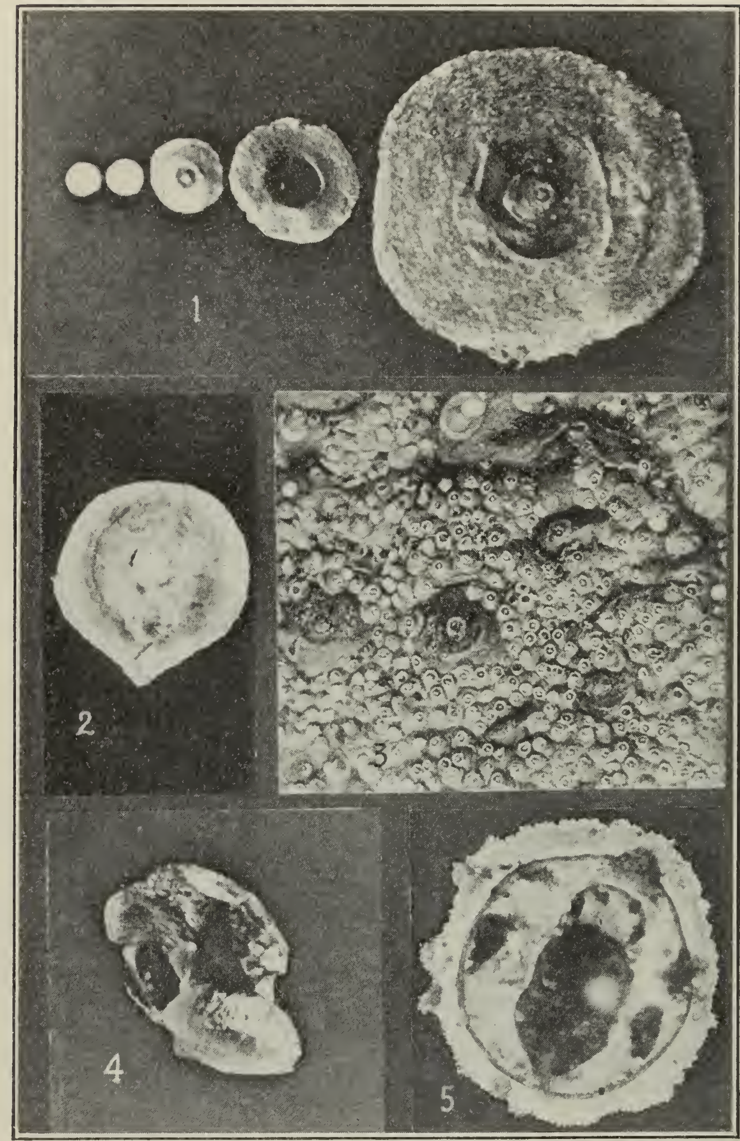

FIG. 10.—1 Different stages in formation of scale covering. 2 The ventral scale formed beneath the insect. 3 Old and young red scales on orange. 4 Larva of parasite, *Aphelinus diaspidis,* feeding on Red Scale; the scale shriveled from absorption of body contents. 5 Yellow scale containing pupa of parasite *Aspidiotiphagus citrinus.*

covering is still transparent enough to see plainly the insect beneath. By this time the insect itself has shortened in length, while its width is increased, and it thus becomes almost circular. While this covering is being secreted the insect beneath revolves about for the purpose of molding the covering in the proper form.

It is generally assumed that the insertion of the beak into the plant tissue is a necessary preliminary operation to the secretion of the covering. On this point our observations, in general, seem to agree, but the actual operation of inserting the beak can not be seen readily. They have been seen to settle with the beak inserted and then withdrawn again before any covering is started. The withdrawal of the beak has been noted in a few instances, and the process is characterized by more distinct indications than is the case with the insertion. A considerable movement of the body occurs by turning partly around, and also a rapid movement of the legs and antennæ. Certain cases have been observed where the young scales settled on top of an old one and secreted the preliminary covering, yet the depth of the old scale was too great to allow the young one above to reach the plant tissues. In such cases the covering is commenced before the beak is inserted or at least before any food is taken. It often happens, of course, that young settle on the outer margins of the old scales, but here there is no difficulty in reaching through to the plant substance beneath.

The same insect may secrete a new covering for a few times if the old one is removed. A scale covering, one or two days old, was lifted from the insect and again replaced. It accepted the new covering, and four days later it was again lifted, and again replaced. This time the covering was not accepted, but a new covering was secreted. In the case of other insects the covering was permanently removed, and the maximum number of new coverings formed was four. When the covering was removed three or four times or more the insect died.

A couple of days after settling the covering is more compacted, especially on the sides near the surface upon which the insect is resting. The dorsal surface is still light and fluffy, but thick enough to entirely conceal the insect beneath. The form at this time is that of a cap with a flat dorsal surface and straight vertical sides. After a few days this sinks down immediately around the center leaving a small prominence forming the so-called nipple. As the scale covering increases in size, it spreads out with a thin edge forming the margin instead of the vertical wall as was the case earlier. In a week or two all the cottony effect is lost, and the covering becomes a very compacted film. In eighteen to twenty days the cast skin of the insect may be seen incorporated into and forming the greater part of the covering. With the increased size of the insect after the molt it becomes necessary to enlarge the covering,

and this is extended beyond the cast skin, which soon comes to form but the center of the scale covering. A similar cast skin is incorporated into the covering after the second molt which is about twice the size of the first. Thus the two cast skins may be seen forming two nearly concentric circles. The covering is again extended, being secreted and added to the outer margin until the total width may be twice that of the second cast skin. During this formation of the scale the lobes and plates of the pygidium play an important part in molding it into the proper form. The insect during the process, must revolve around to reach the margin with the posterior tip of the body which is capable of being greatly extended or contracted as required.

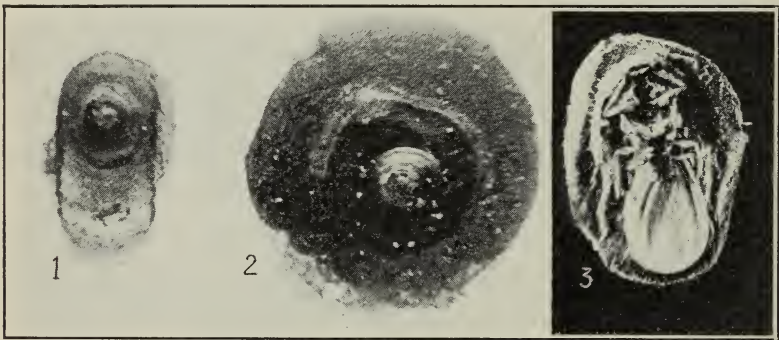

Fig. 11.—1 Scale of male. 2 Scale of female, same magnification. 3 Inverted male scale, showing winged insect beneath.

The above account has reference to the female scale only. The scale of the male is exactly the same until after the first molt, but from that stage on it takes on a very different form from that of the female. The male insect itself during the second stage becomes much more elongate and so the scale covering assumes a corresponding shape. After the first molt the male scale covering widens but little, but increases considerably in length, so that the mature scale is about twice as long as broad. But its extreme length is not as great as the diameter of the mature female scale. The average size of the mature female scale is about 1.5 mm. in diameter, while the mature male scale is about 1 mm. in length.

THE FIXED YOUNG.

Molting. After the insect has settled and the covering secreted it undergoes no change, except to increase in size, until after the first molt. This molt occurs in from fourteen to twenty days after settling. Preliminary to molting, the insect, which, up to this period is readily separated from the scale now becomes firmly attached to it. Previous to this time the body of the insect has a flexible, and somewhat tough covering, and is

not much distended by the contents. But during the molting period, which lasts from three to five days, the body wall is hard and brittle and well distended. The body contents seem to be much more fluid and watery during this period. This change in the body wall and its contents is shown during the handling of the insect with a needle. Between the molts punctures are less likely to occur for the reason of the flexibility of the skin, while it is very readily punctured through the firm distended skin during the molts.

The skin is split around the lateral margin, not only around the general body margin, but often the margin of the lobes and plates also. If the cast dorsal skin be treated in potash the lobes, plates and spines show nearly as clearly as in the insect itself in some of the specimens. If the very frail and almost invisible cast ventral skin be examined most of the pygidial characters will also be seen in some of the specimens. Some times greater detail of the pygidial structures is shown in the ventral and some times in the dorsal cast skin. The figures Nos. 12 and 13 indicate this. In the first ventral skin the legs, antennæ and mouth parts are of course present.

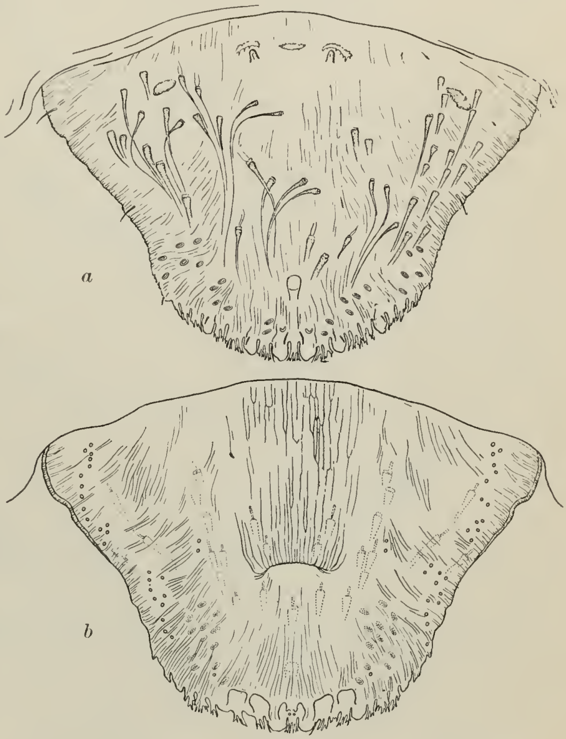

FIG. 12.—*a* Dorsal view of pygidium of Red Scale, x200.
b Ventral cast skin of Red Scale. From same insect as Fig. 13, 3, which is the dorsal cast skin.

The molting of the male differs very strikingly from that of the female excepting the first molt which is the same in both cases. Instead of the skin splitting around the lateral margin as is the case with the female, the rent occurs near the anterior end, and the old skin is pushed backward and from under the scale. These cast skins may often be seen still attached to the posterior tip of the scale.

FIG. 13.—1 A cast skin after first molt. 2 A ventral cast skin, second molt. 3 Dorsal cast skin, second molt, same insect as Fig. 12, *b*, which shows the ventral cast skin. 4 Characters of complete insect. x350.

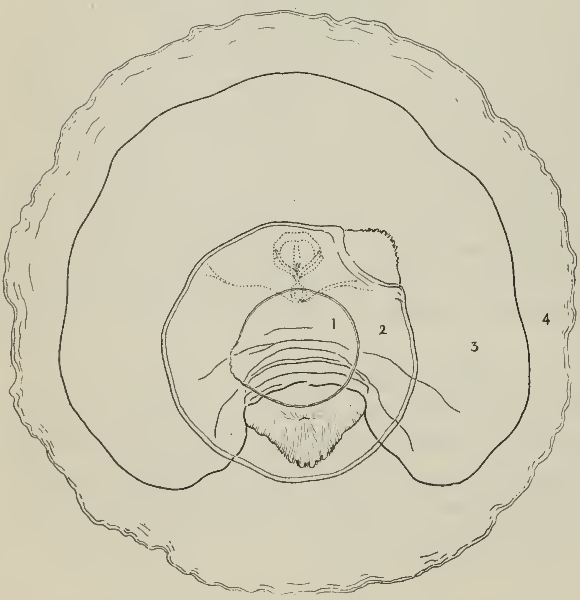

FIG. 14.—Showing the mature Red Scale with its cast skins and the scale covering. 1 First cast skin. 2 Second cast skin. 3 The insect itself. 4 The scale covering. x60.

The second molt of the male insect occurs in about thirty days from birth which brings it to the propupal stage. It remains in this stage about ten days when the third molt occurs after which it is in the true pupal stage. Ten or twelve days are spent as a true pupa when it transforms to the adult. The adult remains beneath the scale from three to five days before emerging. The shortest period re-

quired for the development of the male was found to be 55 days. This was from June 20th to August 14th, which included the hottest weather of the season of 1910. The longest period determined for the development of the male was 112 days. This was from January 2 to May 1, 1909, which included the coldest weather of the season.

THE ADULT MALE.

The male pushes its way backward from beneath the scale and actively walks about immediately after emerging. Upon transforming to the adult it remains beneath the scale for a few days, so that the wings are thoroughly dried and expanded, and is at once strong enough to begin its short period of active life. It usually walks about on the leaf or fruit for a short time, and then flies away. This appears to be a provision to insure the fertilization of females some little distance away, and thus prevent possible degeneration through in-breeding with the females of the same parent which usually settle down in the immediate vicinity. Copulation may occur within a half hour or hour after emergence. The adult life varies from one to five days. The male of this, like most other scale insects, is not a strong flier, but may be greatly aided in prolonged flights by the wind. They appear to be more abundant at certain seasons, and this is particularly true of the early spring. The following table gives the proportion of the sexes according to the time liberated which includes most of the months of the year. It will be seen from this that during the first half of the year the number of males was 74 while the number of females was 42. During the second half of the year the sexes were approximately equal, the table giving 34 for the males and 35 for the females:

FIRST HALF-YEAR.			SECOND HALF-YEAR.		
Young liberated.	Number males.	Number females.	Young liberated.	Number males.	Number females.
January 2	7	3	August 18	2	2
February 24	6	1	September 2	2	1
May 12	7	4	September 3	2	1
May 13	22	8	September 7	1	1
June 3	5	3	September 22	7	2
June 4	3	3	September 22	1	1
June 7	7	4	October 5	5	5
June 17	5	3	October 11	4	2
June 17	2	1	October 13	0	3
June 17	2	3	October 14	2	1
June 18	2	4	October 20	1	2
June 18	2	1	November 10	2	4
June 19	0	3	November 29	0	3
June 19	2	0			
July 24	4	1			
Total	74	42	Total	34	35

THE ADULT FEMALE.

The second molt of the female occurs from 40 to 50 days after birth, which brings it to the adult. It continues to secrete the scale covering after this molt to allow for its increased growth. From 10 to 20 days after the second molt it is fertilized by the male. This is on an average about 60 days from birth. The formation of the scale is entirely completed before the production of young is commenced. During the period the insect is producing young it is similar to that of the molting periods. That is, the insect itself is inseparable from the scale, and the body is rigid and distended.

LENGTH OF ADULT LIFE.

The female scales begin to produce young in about ninety days, and this is continued from one to two months longer, making the total life of the adult from four to five months. In case the female is not fertilized the adult life may be extended much longer. Five females

FIG. 15.—Red Scale, mature females and young.

isolated in cages were perfectly healthy and vigorous and not yet having produced young after a period of five months and twenty-six days. This was during the warmest part of the season, from May 31st to November 25th, when cold was not a factor in retarding development. This fact was learned in connection with the experiments on parthenogenesis. When insects liberated at the same time were fertilized and had completed their production of young the leaves containing the unfertilized scales were unfortunately removed from the tree for examination. This prevented us from obtaining the maximum life of the

unfertilized female, and also from determining if they could, at that late date, be fertilized and still produce their quota of young. This latter fact will very probably be true, but as yet the evidence of actual trial is not at hand. In case the female is not fertilized it thus appears that its development is practically at a standstill for at least three months, or it will live for at least three months after reaching maturity without producing young.

AGE AT WHICH YOUNG IS PRODUCED.

The minimum period from birth to the appearance of young was found to be 73 days. This was from June 20th to September 1st, which included the warmest weather for the season of 1910. This was at Riverside, where the temperature is higher than that of Whittier, where the most of the work was done. Parallel experiments carried on during the same period showed the minimum period from birth to the production of young as 81 days at Whittier.

The maximum period was from February 24th to June 30th, or four

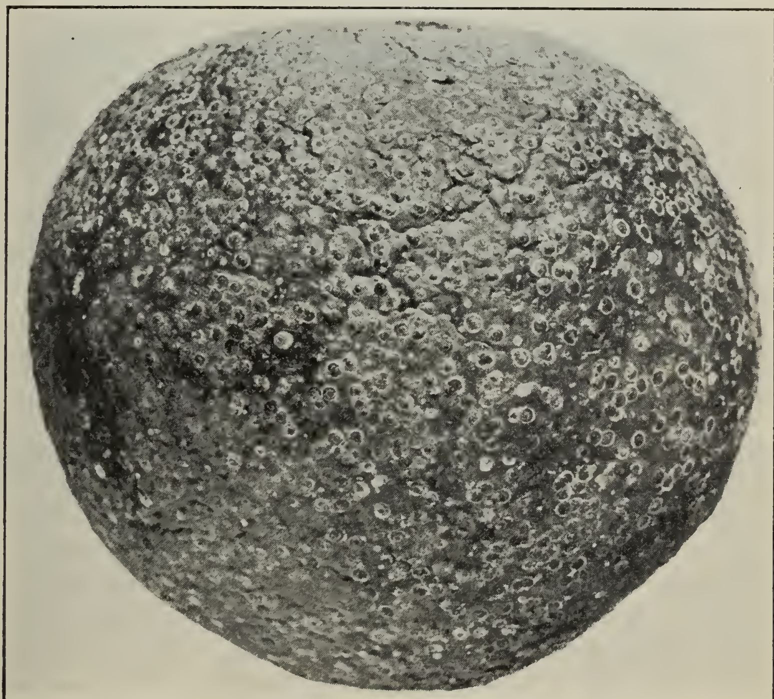

FIG. 16.—Red Scale (*Chrysomphalus aurantii* Mask.) on grape fruit.

months and ten days. Young born on January 2d did not produce adult males until May 1st. Allowing the usual thirty days from fertilization to the appearance of young would make a period of five months.

This represents the maximum for the coldest weather of the season. The age at which young is produced is also dependent upon the time of fertilization. Scales may live for four or five months during the warmest part of the year, and then after fertilization very probably produce young.

ASPIDIOTUS AURANTII—DEVELOPMENT.

Experiment number	Date	Settled.	First molt.	Second molt ♀	Second molt ♂	♂ Propupa	♂ Pupa.	♂ Emerged	♂ Dead.	Young appeared.
14	9-23-08	9-24	--------	--------	--------	--------	--------	11-25	12- 1	1- 2-09
33	1- 2-09	1- 3	--------	--------	--------	--------	4-16	5- 1	5- 5	-------
104	2-24	2-25	3-16	4-20	--------	3-30	4-16	5-11	5-15	6-30
102	2-20	2-21	3-16	4-20	3-30	--------	4- 8	--------	--------	-------
106	2-24	--------	--------	--------	--------	--------	--------	--------	--------	6-26
139	5- 4	5- 6	--------	--------	--------	--------	6-28	--------	--------	8- 6
146	5-12	5-13	--------	--------	--------	--------	--------	7-14	--------	-------
149	5- 9	5-10	--------	--------	--------	--------	7- 3	7-18	7-22	8-10
150	5-19	5-21	6- 4	--------	6-15	6-30	--------	7-21	--------	8-18
151	5-19	5-20	6- 6	7-10	--------	--------	7- 2	7-21	--------	-------
161	5-21	5-23	--------	--------	--------	--------	7-14	7-21	7-26	8- 7
148	5-13	5-14	6- 1	6-30	--------	6-22	--------	7-12	7-16	-------
173	6- 4	6- 5	--------	--------	--------	--------	--------	--------	--------	9- 8
182	6-17	--------	--------	--------	7-12	7-21	--------	--------	--------	-------
183	6-17	--------	--------	7-27	--------	7-21	--------	8-11	--------	-------
184	6-17	6-18	7- 1	--------	--------	7-21	--------	8-11	8-16	-------
187	6-18	--------	7- 3	--------	--------	--------	--------	8-11	--------	-------
189	6-18	--------	--------	7-28	--------	7-21	--------	8-11	8-15	-------
190	6-19	--------	7- 3	--------	--------	--------	--------	--------	--------	9-10
191	6-19	--------	--------	8- 1	7-14	--------	--------	8-14	--------	-------
192	6-19	--------	7- 5	--------	--------	7-17	--------	--------	--------	9-10
193	6-19	--------	--------	--------	--------	7-17	--------	--------	--------	-------
215	7- 2	7- 4	--------	--------	--------	8-11	8-24	--------	--------	-------
214	7- 2	--------	7-17	--------	7-28	8-11	--------	--------	--------	-------
217	7- 3	--------	--------	--------	--------	8-11	8-24	9-10	9-14	-------
256	7-21	7-23	8- 5	--------	--------	8-16	--------	--------	--------	-------
260	7-24	--------	--------	--------	--------	--------	--------	9- 9	--------	10- 6
279	8-12	--------	--------	--------	--------	--------	9-20	10-10	10-14	11-24
285	8-12	8-13	--------	--------	--------	--------	--------	10-12	--------	11-27
311	9- 2	--------	9-18	10-15	--------	--------	10-20	10-29	11- 2	1-18-10
312	9- 3	--------	9-20	--------	--------	--------	--------	10-29	--------	-------
322	9-22	--------	--------	--------	--------	--------	--------	12- 2	--------	-------
323	9-22	--------	--------	10- 5	10-18	10-29	--------	12- 2	12- 6	-------
325	9-22	9-23	--------	--------	--------	10-29	--------	11-30	--------	-------
326	9-22	--------	10-12	11- 6	--------	--------	--------	12- 5	12- 8	-------
327	9-22	9-24	10-14	--------	--------	10-29	--------	--------	--------	1- 2-10
335	10- 5	--------	10-25	--------	--------	--------	--------	1- 2	--------	-------
341	10-11	--------	--------	--------	--------	--------	--------	1-11	--------	-------
342	10-11	--------	10-30	--------	--------	--------	--------	1-15	1-20	-------
347	10-14	--------	--------	--------	--------	--------	--------	1-27	--------	3-25
559	6-17-10	--------	--------	7-20	7-16	7-28	--------	8- 4	--------	-------
561	6-17	--------	7- 3	--------	--------	7-21	--------	--------	--------	-------
563	5-31	--------	--------	--------	--------	--------	--------	7-28	--------	-------
564	5-31	6- 1	--------	--------	--------	--------	--------	8- 1	--------	-------
568	6- 6	--------	--------	--------	--------	--------	7-27	8- 4	--------	-------
569	6- 6	--------	--------	--------	--------	7-12	--------	--------	--------	-------
*570	6-20	--------	7- 4	--------	--------	--------	--------	8-14	--------	9- 1
*571	6-20	--------	--------	--------	--------	--------	--------	--------	--------	-------
*572	6-20	--------	7- 4	--------	--------	--------	--------	--------	--------	9- 2
*573	6-20	--------	--------	--------	--------	--------	--------	8-14	--------	9- 1
Summary av		24 hrs.	16 days	46 days	30 days	38 days	48 days	60 days	65 days	90 days

*At Riverside.

EMBRYONIC DEVELOPMENT.

Since the female comes to maturity and is fertilized by the male about sixty days from birth, and the production of young begins on an average of ninety days, the time required for the development of the egg and the hatching of the larva therefrom within the body of the female, is about thirty days.

FIG. 17.—Greedy Scale (*Aspidiotus rapax* Comst.). Sometimes mistaken for Red Scale.

PARTHENOGENESIS.

Several individual female red scales were isolated as they approached maturity, and no males allowed to reach them. In every case no young appeared under such conditions. These lived for a period of more than six months, with no indication of young appearing. The insect remained in the condition it was after the second molt, that is, it was free from the scale covering and with a pliable body, as opposed to the gravid condition or molting periods, or young-producing periods, as already explained.

EMERGENCE OF YOUNG.

The emergence of young means practically the same as the birth of young, but since the actual birth records can not be obtained without destroying the parent, emergence is used in this discussion rather than birth. This makes no difference in the total number, or the length of the

producing period, though it may make some difference in the rate from day to day. That is, when a sudden drop in the temperature occurs, for instance, the young already born may linger under the scale for a longer period than would otherwise be the case. But the records given show that there is little variation on this point. The maximum number emerged in a single day was found to be eight. But five or six may appear for three or four days in succession, showing that this number must actually be produced on those days.

The records given in the table are for fourteen females, of which daily examination was made throughout the producing period. Many other

FIG. 18.—Red Scale on orange leaf.

records were less accurately made. The period during which young were produced varied from 16 to 63 days, with an average of about 23. The number of young per insect varied from 34 to 143, with an average of 55. The number of young appearing in a day was from 0 to 8. The average number of young per day for the different scales ran from 1.65 to 3.07, with an average for the total number of scales of 2.33. These records on the production of young were made during the months of September and October mostly. September in southern California is a fairly warm month, and during October it seldom gets cool enough to have any marked effect on the activity of the scale. Records on the emergence of young during June and July showed that it was practically the same as that of September and October. Those given, therefore, may be considered as a fair average for the active season from April to November.

EMERGENCE OF YOUNG.

Date, 1910.	Number young	Date, 1910.	Number young	Date, 1910.	Number young	Date, 1910.	Number young	Date, 1910.	Number young
Sept. 20	5	Sept. 21	4	Sept. 24	3	Sept. 25	2	Sept. 28	3
Sept. 21	5	Sept. 22	3	Sept. 25	4	Sept. 26	2	Sept. 29	2
Sept. 22	6	Sept. 23	3	Sept. 26	5	Sept. 27	1	Sept. 30	0
Sept. 23	3	Sept. 24	5	Sept. 27	5	Sept. 28	0	Oct. 1	6
Sept. 24	2	Sept. 25	1	Sept. 28	0	Sept. 29	0	Oct. 2	0
Sept. 25	5	Sept. 26	0	Sept. 29	1	Sept. 30	3	Oct. 3	8
Sept. 26	4	Sept. 27	3	Sept. 30	3	Oct. 1	4	Oct. 4	3
Sept. 27	0	Sept. 28	4	Oct. 1	3	Oct. 2	8	Oct. 5	4
Sept. 28	0	Sept. 29	3	Oct. 2	4	Oct. 3	8	Oct. 6	7
Sept. 29	0	Sept. 30	0	Oct. 3	3	Oct. 4	8	Oct. 7	4
Sept. 30	0	Oct. 1	4	Oct. 4	2	Oct. 5	7	Oct. 8	4
Oct. 1	2	Oct. 2	1	Oct. 5	3	Oct. 6	5	Oct. 9	4
Oct. 2	3	Oct. 3	0	Oct. 6	2	Oct. 7	8	Oct. 10	4
Oct. 3	4	Oct. 4	0	Oct. 7	3	Oct. 8	8	Oct. 11	2
Oct. 4	4	Oct. 5	1	Oct. 8	2	Oct. 9	5		
Oct. 5	0	Oct. 6	0	Oct. 9	3	Oct. 10	4		
Oct. 6	1	Oct. 7	0	Oct. 10	2	Oct. 11	5		
Oct. 7	0	Oct. 8	0	Oct. 11	3	Oct. 12	4		
Oct. 8	2	Oct. 9	0	Oct. 12	3	Oct. 13	2		
Oct. 9	6	Oct. 10	1	Oct. 13	2	Oct. 14	2		
Oct. 10	6			Oct. 14	1	Oct. 15	0		
Oct. 11	5			Oct. 15	0	Oct. 16	0		
Oct. 12	1			Oct. 16	3	Oct. 17	0		
Oct. 13	2			Oct. 17	0	Oct. 18	2		
Oct. 14	4			Oct. 18	3	Oct. 19	1		
Oct. 15	1			Oct. 19	1				
Oct. 16	0								
Oct. 17	0								
Oct. 18	0								
Oct. 19	2								
Oct. 20	1								
Oct. 21	2								
Oct. 22	1								
Oct. 23	2								
Oct. 24	4								
Oct. 25	0								
Oct. 26	3								
Oct. 27	4								
Oct. 28	1								
Oct. 29	2								
Oct. 30	3								
Oct. 31	2								
Nov. 1	4								
Nov. 2	0								
Nov. 3	2								
Nov. 4	0								
Nov. 5	2								
Nov. 6	3								
Nov. 7	2								
Nov. 8	2								
Nov. 9	3								
Nov. 10	2								
Nov. 11	3								
Nov. 12	2								
Nov. 13	4								
Nov. 14	2								
Nov. 15	3								
Nov. 16	2								
Nov. 17	3								
Nov. 18	0								
Nov. 19	3								
Nov. 20	2								
Nov. 21	2								
Total	143	Total	33	Total	64	Total	89	Total	43
Days	63	Days	20	Days	26	Days	25	Days	14
Av. per day	2.25	Av. per day	1.65	Av. per day	2.46	Av. per day	3.56	Av. per day	3.07

EMERGENCE OF YOUNG—Continued.

Date, 1910.	Number young	Date, 1910.	Number young	Date, 1910.	Number young	Date, 1910.	Number young	Date, 1910.	Number young
Sept. 28	8	Sept. 29	2	Sept. 29	7	Sept. 1	4	Oct. 1	1
Sept. 29	3	Sept. 30	1	Sept. 30	4	Sept. 2	4	Oct. 2	1
Sept. 30	1	Oct. 1	0	Oct. 1	5	Sept. 3	1	Oct. 3	2
Oct. 1	4	Oct. 2	1	Oct. 2	4	Sept. 7	1	Oct. 4	1
Oct. 2	2	Oct. 3	1	Oct. 3	3	Sept. 9	1	Oct. 5	3
Oct. 3	3	Oct. 4	1	Oct. 4	4	Sept. 10	1	Oct. 6	4
Oct. 4	5	Oct. 5	3	Oct. 5	4	Sept. 12	2	Oct. 7	2
Oct. 5	6	Oct. 6	4	Oct. 6	4	Sept. 13	1	Oct. 8	3
Oct. 6	6	Oct. 7	3	Oct. 7	4	Sept. 14	1	Oct. 9	4
Oct. 7	8	Oct. 8	4	Oct. 8	4	Sept. 15	0	Oct. 10	3
Oct. 8	4	Oct. 9	5	Oct. 9	5	Sept. 16	2	Oct. 11	0
Oct. 9	3	Oct. 10	4	Oct. 10	6	Sept. 17	1	Oct. 12	2
Oct. 10	0	Oct. 11	3	Oct. 11	3	Sept. 19	0	Oct. 13	4
Oct. 11	0	Oct. 12	0	Oct. 12	0	Sept. 20	1		
Oct. 12	0	Oct. 13	2	Oct. 13	1	Sept. 21	1		
Oct. 13	3	Oct. 14	3	Oct. 14	0	Sept. 22	2		
Oct. 14	1	Oct. 15	2	Oct. 15	1	Sept. 23	1		
		Oct. 16	1	Oct. 16	0	Sept. 24	2		
		Oct. 17	0	Oct. 17	0	Sept. 25	0		
		Oct. 18	11	Oct. 18	2	Sept. 26	1		
		Oct. 19	1			Sept. 27	0		
						Sept. 28	0		
						Sept. 29	0		
						Sept. 30	2		
						Oct. 1	0		
						Oct. 2	1		
						Oct. 3	0		
						Oct. 4	1		
						Oct. 5	1		
						Oct. 6	0		
						Oct. 7	0		
						Oct. 8	1		
						Oct. 9	1		
						Oct. 10	1		
						Oct. 11	1		
						Oct. 12	2		
Total	57	Total	42	Total	61	Total	38	Total	30
Days	17	Days	21	Days	20	Days	42	Days	13
Av. per day	3.35	Av. per day	2	Av. per day	3.05	Av. per day	.90	Av. per day	2.30

EMERGENCE OF YOUNG—Continued.

Date, 1910.	Number young	Date, 1910.	Number young	Date, 1910.	Number young	Date, 1910.	Number young
October 1	1	October 1	1	October 4	5	October 5	4
October 2	1	October 2	0	October 5	5	October 6	6
October 3	1	October 3	0	October 6	6	October 7	5
October 4	0	October 4	0	October 7	5	October 8	5
October 5	1	October 5	1	October 8	6	October 9	4
October 6	2	October 6	2	October 9	3	October 10	5
October 7	1	October 7	1	October 10	3	October 11	4
October 8	2	October 8	0	October 11	3	October 12	2
October 9	3	October 9	0	October 12	1	October 13	0
October 10	3	October 10	0	October 13	4	October 14	1
October 11	2	October 11	5	October 14	1	October 15	0
October 12	6	October 12	7	October 15	0	October 16	2
October 13	2	October 13	5	October 16	2	October 17	2
October 14	2	October 14	6	October 17	2	October 18	3
October 15	2	October 15	2	October 18	3	October 19	3
October 16	1	October 16	2	October 19	1	October 20	4
October 17	1	October 17	2				
October 18	0	October 18	3				
October 19	3						
Total	34	Total	37	Total	50	Total	50
Days	19	Days	18	Days	16	Days	16
Av. per day	1.79	Av. per day	2.05	Av. per day	3.12	Av. per day	3.12

Grand total number of young	771
Number of days producing	330
Average number per day	2.33
Number of insects	14
Average number young per insect	55
Average producing period, days	23.57

DO THE INSECTS MOVE AFTER BECOMING FIXED?

The statement has appeared that the red and yellow scales, particularly the yellow, may move after becoming fixed. This statement is based upon no evidence, but upon the fact that there appears a distinct streak of yellow tissue showing where the beak has been inserted, and this being too long to be produced without some movement of the scale. Several dozen scales, both red and yellow, were surrounded by India ink to determine this point, but none were found to move in the slightest degree. It was observed that in the formation of the scale it was extended under the film of ink. The circle of ink on the leaf, which just surrounded the young scale was later resting on the scale itself, which had extended under and beyond the ink film.

Both the red and yellow scales, but especially the yellow, often produce a yellowish spot about the point of puncture. This often shows through on the opposite side of the leaf. Sometimes this spot is much larger than the scale itself. It may appear in a uniform circle with the scale as a center, and again, the discoloration may be all on one side. The size, shape and position of the spot may thus vary considerably. That the spot is due to the extraction of the chlorophyll from the cells,

or from the toxic effect of the insertion of the beak, seems well established. It is most usual for the yellowing to appear in circular spots, and these areas may be much larger than can be reached by the beak. That these areas should sometimes take on different forms, even to the extent of a narrow streak, is not improbable, and it is hardly necessary to take the movement of the scale into consideration to account for it. Another point against any movement is the fact that the flimsy ventral cast skins are always found directly beneath the mature insect. It is scarcely possible that these would be pulled along with it.

SEASONAL HISTORY.

The average length of the life cycle from the active young to the appearance of young again is about three months. During the warmer weather it will run slightly under this, and during the coldest weather it will run considerably more, the extremes being from 72 days to nearly 150 days. Four generations a year will be the largest number in a season. It is not unlikely that this number occurs in the warmer sections—as Redlands and Riverside. But in most sections three generations, with a partial fourth, will represent the actual conditions. Starting with April 1st, the beginning of the next generation will be about July 1st. Those young appearing at this time will be producing young themselves by the first of October. This will make two generations during the months of greatest activity. Those young appearing in October may not, as our life history work has shown, give rise to young again before February or March. This makes three full generations, with a partial fourth, for conditions as they obtain at Whittier.

ANNUAL PROGENY.

It is a well known fact that citrus trees may become very severely infested with red scale in a single year, and with a two years' infestation a large portion of the tree may be killed. This often happens after the grove has been fumigated, and it is charged that the fumigation has not been effective. This may or may not be the case. But even if the fumigation has not been well done, if the scale is carried in from a neighboring grove, the trees will be badly infested again within a year; this is accounted for through the rapid multiplication of the insect. While the number of young from a single individual is not nearly so large as that of the black scale—not more than one fortieth as large—the increased number of generations make the number much greater at the end of the year. Counting the average number of young produced by a single red scale at 55, and allowing one half of this number for males, the number at the end of the third generation will be more than 40,000, and the number at the end of the fourth generation will be more than a

million. These figures include the males, but since the males feed during the first two stages, or for a period of thirty days, they must be counted as injuring the plant, but of course not to such an extent as the females. While, therefore, a black scale may produce forty times as many young as the red, the progeny from a single red scale at the end of a year, with four generations, will be five hundred times as many as the progeny of the black, which has but one generation. Only a small per cent of these, to be sure, actually comes to maturity, but it is an indication of what might be approached if all conditions were favorable.

MORTALITY.

One of the most critical periods in the life of the red scale is during its active larval period. Not only is it more exposed to the attack of enemies of all kinds, but its own failure to become established is a serious check on its numbers. The actual figures given earlier in this account show that, under the favorable conditions of being protected from outside agencies, the number settling amounts to but 41 per cent of those that are active. More than one half is thus lost before they have scarcely started on their life cycle. Many of those that do settle fail for one cause or another to reach maturity. The molting periods are other critical stages, and many fail to pass successfully through these. Weather conditions may also be factors tending to decrease their numbers, but these are not so specifically isolated as in the case of the influence of hot weather on the black scale. Parasites and predatory enemies are other agencies that affect the number of the red scale in all stages, but these will be discussed later.

LOCOMOTION AND SPREAD.

The red scale, like most other scale insects, is distributed over long distances mainly through the interchange of nursery stock or the marketing of fruit. This scale very readily attacks the fruit, and they may live on this, as in case of the lemon, for many months after being harvested. Professor Coit of this station wrapped a few lemons in ordinary newspaper and stored them away in his house on December 5, 1909. These apparently had a few scattering scales which were not noticed at the time of storing. On June 30, 1910, or nearly seven months later, these were unwrapped, and upon examination were found to be badly infested with the red scale. Altogether there were 35 adults, and between 800 and 900 young, all alive. The adults were those present when the fruit had been stored, and, at the time, were probably not very fully developed. But they completed their development, and after an interval of seven months young were still appearing. In this time the fruit, had it been in transit, would have had time to reach most any

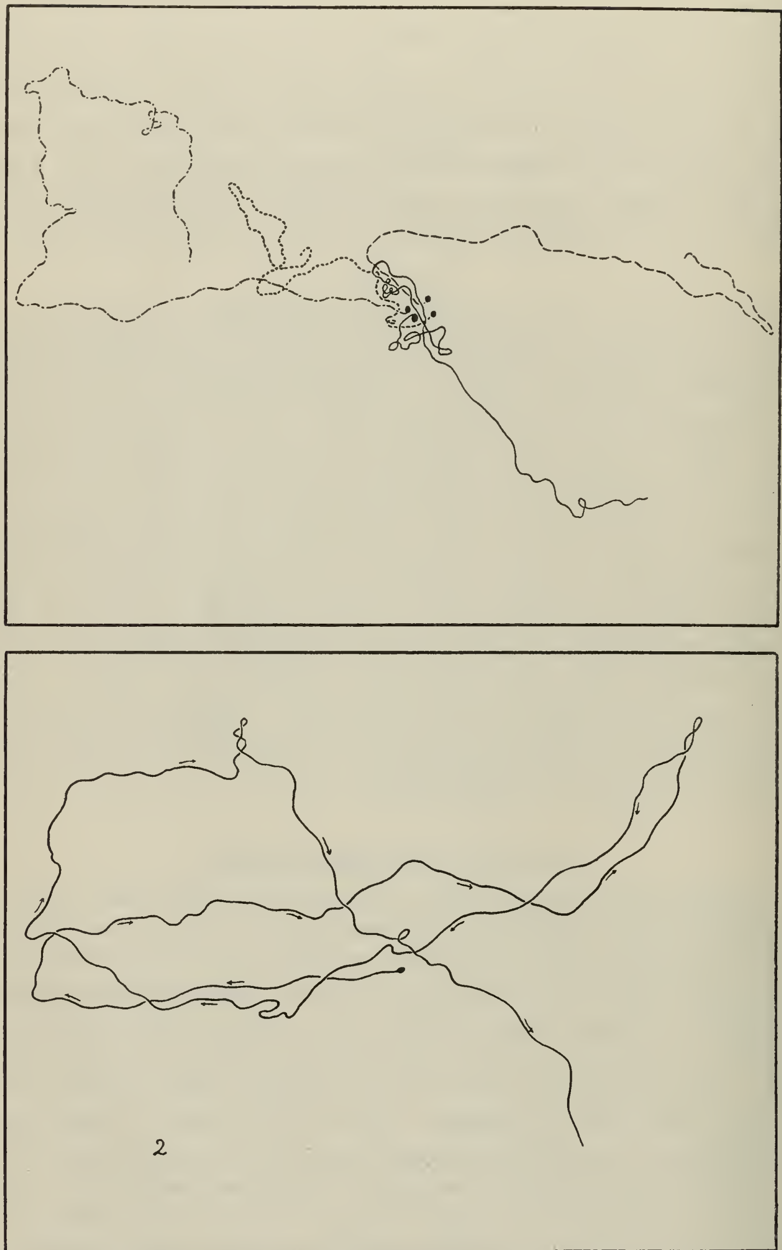

FIG. 19.—Tracings showing actual movement of motile young red scales for a two-hour period. Reduced seven times. 1 Temperature 66°; average distance traveled, 31 inches. 2 Temperature 91°; average distance 111 inches.

part of the world. An interesting point with these scales was that they were very light gray or grayish white in color, and were mistaken at first for the greedy scale (*Aspidiotus rapax*). This striking difference in color from the usual red must be accounted for from the absence of light, since they were securely wrapped in paper during all the period.

The spread of the red scale over the same general community is effected largely by birds and active insects, together with the agency of man in his usual cultural operations. In the spread from tree to tree, aside from the above factors, the power of the insect to transport itself is entitled to consideration.

Rate of travel over smooth surfaces. With a view to determining how far a red scale would travel under the most favorable conditions, records were made for two hour periods on smooth paper. When the temperature was 66°F. four active young red scales traveled 23, 25.5, 34, and 41 inches, respectively, or an average of 31.12 inches. Under the same conditions, when the temperature was 91°F., the maximum distance traveled was 111 inches, or more than three times the distance. Several other experiments on the rate of travel over paper showed similar results.

A young red scale is active for from twenty-four hours to two or three days. Very rarely have they not settled within one or two days. But taking the maximum period of activity, under conditions where no food is available at four days, the total distance traveled might be 444 feet. This is on the basis that they would travel 55.5 inches per hour, and keep it up continuously for four days. This distance, of course, would never be approached under actual conditions. Two active young were liberated on an ordinary picking box, and one crawled eleven inches and the other six inches in one hour. The temperature was 80° F. This test was duplicated with a temperature of 96° F., and the longest distance covered in one hour was eleven inches, and the shortest distance eight inches. We have not yet succeeded in getting the young red scale to live more than four days without food. Picking boxes, gloves, ladders, etc. would therefore be safe to take into a clean grove without fear of infestation through these things after a period of four or five days, or, to be surely on the safe side, one week.

Rate of travel over sand and orchard soil. A number of experiments were made on the rate of travel of the young insects over sand and orchard soil. Some of these are tabulated below:

Date.	Temperature.	Number insects.	Kind of soil.	Radius of soil.	Time.	Results.
July 15	90°F.	15	Sand	1 inch	4 hrs.	0 crossed
July 15	90	15	Sand	2½ inches	4 hrs.	0 crossed
July 15	90	15	Sand	3 inches	4 hrs.	0 crossed
July 18	88	20	Sand	2½ inches	17 hrs.	1 crossed
July 19	85	20	Orchard-soil	2½ inches	17 hrs.	0 crossed
July 18	85	20	Orchard-soil	2 inches	5 hrs.	0 crossed
July 18	85	20	Orchard-soil	2 inches	14 hrs.	0 crossed
July 22	89	15	Orchard-soil	2 inches	18 hrs.	0 crossed
July 20	93	20	Orchard-soil	3 inches	15 hrs.	0 crossed
July 21	82	20	Orchard-soil	3 inches	19 hrs.	2 crossed
July 23	63	10	Orchard-soil	3 inches	19 hrs.	2 crossed
July 24	78	20	Orchard-soil	3 inches	24 hrs.	2 crossed
July 25	78	25	Orchard-soil	3 inches	24 hrs.	0 crossed
July 25	76	20	Orchard-soil	3 inches	24 hrs.	0 crossed
Nov. 29		18	Sand	2½ inches	24 hrs.	2 crossed
Nov. 29		18	Sand	2½ inches	24 hrs.	1 crossed
Nov. 26		12	Sand	2 inches	24 hrs.	2 crossed
Nov. 19		12	Sand	1 inch	24 hrs.	2 crossed
July 18	88	2	Compacted silt	5 inches	30 min.	2 crossed
July 18	88	2	Compacted silt	5 inches	20 min.	2 crossed

From the above experiments it will be seen that the young red scale makes very little progress over sand or ordinary orchard soil. Out of the 319 insects tried only fourteen crossed over the strips of soil indicated, which did not exceed three inches in width. None of them succeeded in crossing even the narrowest strips until the following day. In the case of the last two tests, where the soil was compacted in an irrigation furrow, they made very good progress, and traveled at the rate of about ten inches an hour. If, then, there is a fairly good mulch, as is maintained in California citrus orchards during the summer, there is little chance of a young red scale ever making its way from one tree to another by its own powers of locomotion. But during the winter season when the surface soil is compacted by rains, or through irrigation during the summer, there may be some possibility of this occurring. In the case of the mulch the young scales, in attempting to ascend a small particle of earth, fall back in the attempt and flounder about without making very much progress.

On account of the limited powers of locomotion of the insects themselves, their spread must be accounted for through outside agencies. Of these, active insects must be the most important. Among the insects responsible for their spread, those which are to be found crawling about on the tree where the scales are are most important. Coccinelids are, therefore, entitled to first consideration. These may be feeding on the scales themselves, and thus allow abundant opportunity for the young scales to crawl upon them. Indeed, it has not been uncommon to actually

observe many of the beetles carrying young scales on their bodies in the insectary and also in the field. Others, such as lace wing flies, Diabrotica, and ants are likely to aid in the spread of young scale insects.

The wind is hardly as important as popularly believed in aiding the spread of scales. Of course the adult male may be carried some distance by the wind, but the active young are too heavy for their size to be transported very far. They are not easily dislodged from the tree by the wind, but once dislodged may be carried a short distance while they are falling, if the wind is sufficiently strong. But the wind is likely to be more important in distributing infested leaves about. Here, again, it is the dead leaves that are conveyed most easily, and these are not so likely to have live scales as the green or yellowed ones.

FIG. 20.—*Aphelinus diaspidis.* 1 Egg. x15. 2 Larva. x65. 3 Head segment showing mandibles. 4 Pupa. x60.

PARASITES.

Aphelinus diaspidis Howard.

The most common parasite of the red scale at the present time is *Aphelinus diaspidis* Howard. Indeed, in the examination of red scales from many parts of the citrus belt during the past three years this has been practically the only one met with in any numbers. In the literature that has appeared, and addresses made in this state on parasites, this particu-

FIG. 21.—*Aphelinus diaspidis* How. Parasite on Red and Yellow Scales. x39.

lar insect has not been mentioned in connection with the red scale. It may be possible that it has recently become prominent, or that it was considered under another name. It is true that the parasites of the red scale have received less attention than those of some of the other scales. That it has become abundant rather recently is not impossible. *A. diaspidis* was first described by Dr. L. O. Howard in 1880 from specimens bred from *Aulacaspis rosæ* from Florida. Specimens from the same scale were also collected at Santa Barbara, California, about the same time. It has, therefore, been known from this State for thirty years. This parasite has also been bred from a species of *Mytalispidis* from Japan and from *Aspidiotus juglans regia,* or the walnut scale.

It has been usual here to speak of such a parasite as this of the red scale as an internal parasite, but this is not strictly true, for at no stage of its life cycle is it within the insect. It is true that all of its life, excepting as an adult, is spent beneath the scale covering, but it is always outside the insect itself. The egg is deposited outside of the insect, and upon hatching the larva attaches itself to the body and sucks out the juices. In the case of the yellow scale parasite *Aspidiotiphagus citrinus,* which also attacks the red, it lives within the body of the insect and is strictly an internal parasite. *Coccophagus lecanii* and *Aphycus flavus,* parasites of the soft brown scale (*Coccus hesperidum*) are also strictly internal parasites; that is, they live within the body of the insect and entirely surrounded by the body tissues from which their food supply is derived.

ECONOMIC VALUE.

While it is not uncommon to find this parasite on red scale from many sections of the citrus belt, it has never been seen occurring in large numbers. Examination and counts have been made at various times during the past three seasons, and, thus far, we have not found the number of scales parasitized to exceed 10 per cent. This amount of parasitization is, of course, of little value in checking the number of scales. The parasite was usually found most abundant where the scales were most numerous.

DESCRIPTION OF THE STAGES.

The egg is yellowish white in color, ovate in form, measuring .16 mm. long and .96 mm. wide. There is a conspicuous micropyle projecting from the narrower end and also attached to this a short stalk that is doubled back on itself. The chorion is smooth, with spherical granular bodies showing through with transmitted light.

The larva when full grown appears as a more or less structureless top-shaped globule, measuring, when segments are normally extended, .75 mm. long and .5 mm. wide. It tapers considerably more toward the

posterior end, and there is a slight difference between the dorsal and ventral surfaces. The distance between the upper and lower surfaces is a little less than the width of the body so that there is some indication of flatness. The color is glassy white, with the food in the digestive tract showing distinctly yellow, oval in shape, and measuring about one half the dimensions of the larva itself. There are thirteen indistinct segments, not including the button at the tip. The head end is broadly rounded, with the first segment disc-shaped and firmer than the others, with the small mouth opening in the center. This mouth opening is about .20 mm. in diameter, and there are two chitinous spines, mandibles, projecting toward its center in front. These spines are .18 mm. in length and .15 mm. wide at the base where the muscle attachment occurs. From near the base they suddenly narrow into a sharp pointed spine which is chitinous at tip and brown in color. These are used for piercing the outer wall of the scale and for holding it in place while the fluids are sucked from the body.

The pupa is dark yellow in color, with ocelli and eyes reddish brown, and a similar pigment extending around the anterior margin, and to a less extent about the posterior margin of the head. Length .75 mm., width .375 mm. The adult appendages, enclosed in their sheaths, lie close to the body on the ventral side. Always accompanying the pupa are from six to ten black or dark brown torpedo like bodies .125 mm. long and .055 mm. broad, which are evacuations from the digestive tract and are expelled by the larva preliminary to pupation.

The adult. Length .78 mm., wing expanse 1.9 mm., general color yellow, eyes black, ocelli dark red, antennæ dusky and darker at tip. The eyes are not covered with hairs. The antennæ are six jointed, the club being about three times the length of the penultimate point. The fringe of the wings is narrow.

LIFE HISTORY AND HABITS.

The duration of the egg stage is from four to five days, of the larval stage twelve to sixteen days, and of the pupal stage eight to ten days. The adult, under nearly normal conditions, usually died in four or five days.

This parasite does not always emerge through an exit hole in the scale, but very commonly simply pushes its way out from under the scale. The scale covering seems to be loosened from the surface in most cases so that this means of emergence is comparatively easy. This is further brought about by the movement of the parasite, and also because of the fact that the scale covering is always separated from the insect and has a chance to loosen before the parasite is mature. In case, however, the scale covering is held securely to its resting surface the parasite eats out an irregular hole in the scale covering just beyond the molted skin, in

the case of female scales, and at the posterior third in the case of male scales. The parasite almost invariably is lying on its back as a pupa. Not infrequently two pupæ are found under one scale, and one case has been observed where there were three.

The egg is deposited under the scale covering, but either on the upper or lower side of the insect itself, most commonly on the lower. It is not inserted within the body of the insect. Preliminary to oviposition a thorough examination is made of the scale by alternately tapping with the antennæ from the center of the scale to the periphery. Upon reaching the edge of the scale a rapid backward movement is made, at the same time turning slightly around so that the entire surface is explored by the antennæ in from five to eight backward and forward movements in a remarkably short time. This procedure may occur with but one scale before the ovipositor is inserted, and again a dozen or more may be gone over without finding a suitable scale for oviposition. But the parasite does not rely alone on the exploration with the antennæ, for the ovipositor may be inserted many times without any eggs being deposited. Insertion with the ovipositor may occur with the insect beneath in various conditions, and not infrequently it is dead and shriveled up. But exploration by the ovipositor is the final reliance for the placing of the egg.

The ovipositor is not inserted under the scale covering, but through it just beyond the insect beneath. The parasite is facing away from the scale during oviposition so that the ovipositor is pushed down and backward toward the center of the scale.

A specific case will serve to illustrate the behavior during oviposition. Parasite inserted ovipositor and laid egg in scale No. 1 occupying five minutes. One insertion was made in each of three other scales occupying from one to three minutes each. No eggs deposited. In scale No. 5 ovipositor inserted eleven times, and remaining in scale as follows: 1 min.; $\frac{3}{4}$ min.; 1 min.; $1\frac{3}{4}$ min.; 1 min.; 1 min.; $1\frac{1}{4}$ min.; 1 min.; $\frac{3}{4}$ min.; $1\frac{1}{2}$ min.; $6\frac{3}{4}$ min. Scale lifted and but one egg deposited, this undoubtedly at last insertion.

Eggs may be deposited under scales of various stages as follows: Female between first and second molt and between second molt and egg laying. Male after first molt, propupa and pupa. In no case has a larva of the parasite been seen with a scale during the molting periods or during the egg-laying period. The scale during these periods is very different than at other times. The body wall is hard and glassy, while the contents are more fluid and the insect adheres firmly to the scale covering. Between the molts the body wall is flexible, is not so distended by the body fluids, and the scale covering very readily separates from the insect itself. This last point accounts for the readiness with which the covering is lifted in many cases to allow the escape of the parasite.

The fact that the parasite has not been seen infesting a scale during the molting periods or the egg-laying stage is accounted for because of the checking in growth of the scale. So far as our observations have gone, eggs are not deposited under scales in these conditions. The effect of the parasite on the host seems to be the only explanation for the fact that molting may not occur later, and before the parasite has developed. The feeding of the parasite larva seems to check the development of the scale as soon as it is attacked, or soon thereafter.

Some of the Chalcid parasites have been recorded as feeding at the puncture holes made by the ovipositor.[1] This has not been observed in the case of *A. diaspidis*. Several hundred insertions of the ovipositor have been watched during the past two or three years, so that such a habit can not be, at least, counted common. The egg parasites mentioned in the article cited would be able to get the drop of the contents which would almost certainly be exuded. But we are not so sure that any liquid would be exuded in the case of a puncture in the scale covering of some of the armored scales.

This would be possible during the molting periods, or the egg-laying period, when the body is well distended and intimately associated with the scale covering. But *A. diaspidis* has not been seen to oviposit under such scales. And at other times, while the ovipositor is inserted through the scale covering, it does not puncture the insect itself, or if it does, the liquid would be apt to exude underneath the covering and not necessarily through the puncture hole. Such a habit would be more likely to occur with those parasites that deposit their eggs within the body of the host, instead of externally as *diaspidis*.

Observations have been made on this species feeding on a droplet of honey dew and also some indication that they feed on plant tissue. They have been observed many times lying prone upon the surface of the fruit or leaf working the mandibles and going through all the movements of feeding. But no feeding scars have been seen with the lower power lenses. *Coccophagus lecanii* has this habit, and leaves very distinct feeding scars. It also strokes the soft brown scales to secure the drops of honeydew similar to the ants. No males of *A. diaspidis* have yet been seen, although a large number of specimens have been collected from various places. Parthenogenetic reproduction, therefore, must be the usual way. An isolated female that had emerged was immediately placed in a glass vial, and an hour or two later deposited an egg beneath a scale and which later hatched.

[1]Howard. Jour. Ec. Entomology. Vol. 3, No. 3.

Other species of Hymenopterous parasites reared from the red and yellow scales in California are:

Prospaltella aurantii Howard.
Coccophagus lunulatus Howard.
Aspidiotiphagus citrinus Craw.
Signiphora occidentalis Howard.
Aphycus immaculatus Howard.
Alaptus criococci Girault.
Physcus flaviventris How., has been reared from *Chrysomphalus aurantii* Mask. from Manila, P. I.

KEY TO THE SPECIES OF PARASITES RECORDED FROM *Chyrsomphalus aurantii* AND THE VARIETY *citrinus*.

Antennæ 6-jointed.
- Wings with short fringe, *Aphelinus diaspidis*.
- Wings with long fringe, *Signiphora occidentalis*.

Antennæ 7-jointed.
- *Physcus flaviventris*.

Antennæ 8-jointed.
- Stigmal vein lacking; fringe long, *Aspidiotiphagus citrinus*.
- Stigmal vein present; fringe short.
  - Marginal vein as long or longer than submarginal, *Coccophagus lunulatus*.
  - Marginal vein much shorter than submarginal, *Prospaltella aurantii*.

Antennæ 9-jointed.
- *Aphycus immaculatus*.

Antennæ of female 8-jointed, of male 10-jointed.
- *Alaptus eriococci*.

Prospaltella aurantii Howard.

This species was originally described by Dr. Howard in Insect Life, Vol. VI, p. 231, in 1894. The specimens were reared by D. W. Coquillett from *Chrysomphalus aurantii* var. *citrinus* from San Gabriel, California, in 1887. The original generic name was given as *Coccophagus*, and later as *Prospalta*, but the latter was preoccupied so that the genus as it now stands is *Prospaltella*.[1]

FIG. 22.—*Prospaltella aurantii* How. x50. After Howard.

This parasite is not common on the red or yellow scales, and is only occasionally met with. It is also recorded from *Aspidiotus ancylus, A. pini, A. juglans regia, Lepidosaphes beckii, L. alba, Eulecanium persicæ, Chionaspis* sp.[2]

Coccophagus lunulatus How.

This parasite was described from one female reared from *Chrysomphalus aurantii* from Los Angeles in 1892. Red scale infested leaves

[1]Howard. Jour. Ec. Ent. Vol. 4, No. 1, 1911.
[2]Howard. Tech. Series I, Bull. U. S. D. A., Bur. Ent., 1895.
[3]Howard. Insect Life. Vol. VI, p. 232.

were placed in a jar and a week later the above parasite issued.[3] There is some doubt in the writer's mind about this insect being reared from the red scale. Species of the genus *Coccophagus,* with this single exception, do not attack members of the *Diaspinæ* group. The size of the

FIG. 23.—*Coccophagus lunulatus* How. x50. After Howard.

parasite is also rather large to mature in a red scale. The size as given in the original description is .93 mm., while the average dimensions of the mature scale are .78 mm. wide and 1 mm. long. The lengths of the other parasites of this same host are .61 mm., .55 mm., .53 mm., .58 mm., and .70 mm. It would not be unlikely that it issued from *Coccus hesperidum,* which are so frequently found on the orange leaves.

Aspidiotiphagus citrinus Craw.

A discussion of this insect will be found under the head of "Yellow Scale Parasites."

Signiphora occidentalis How.

This insect was described by Dr. Howard from material reared from *Chrysomphalus aurantii* var. *citrinus,* from San Gabriel, California. It has also been taken from *Lepidosophes gloverii, Aspidiotus cydoniæ* and *Aleyrodes* sp. The original description is given in Insect Life, Vol. VI, p. 235.

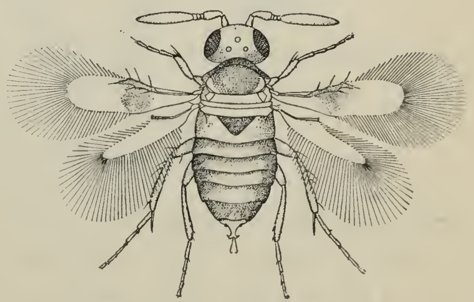

FIG. 24.—*Signiphora occidentalis* How. x50. After Howard.

Aphycus immaculatus How.

This species has been reared by D. W. Coquillett from *Chrysomphalus aurantii* from Los Angeles, California, and described by Dr. L. O. Howard in Insect Life, Vol. VI, p. 236. It has not been observed by us during the past three years.

FIG. 25.—*Aphycus immaculatus* How. x50.
After Howard.

Alaptus eriococci Girault.

This species has been reared from *Chrysomphalus aurantii* and *Rhizoccus araucariæ* from Los Angeles, and described by Mr. A. A. Girault in the Annals of the Ent. Soc. of America, Vol. I, No. 3, 1908.

FIG. 26.—*Aphelinus* sp. Larva, pupa, adult. Reared from *Aspidiotus hederae* Vall.

PREDATORY ENEMIES.

Rhizobius lopanthæ. Blaisd.

This *Coccinelid* is probably the commonest and most abundant one feeding upon the red scale. While it is not restricted in its feeding to this scale exclusively it has been found more often associated with it than any of the other scales, unless it be the purple. It has been called the "Purple Scale Rhizobius," but this name is no more justifiable than

"Red Scale Rhizobius." In fact, the latter would be an appropriate common name just as the "Black Scale Rhizobius" would be similarly appropriate for *Rhizobius ventralis*. Where both the red and black scales occur in the same orchard, or even on the same tree, *ventralis* will be found with the black and *lophanthæ* with the red.

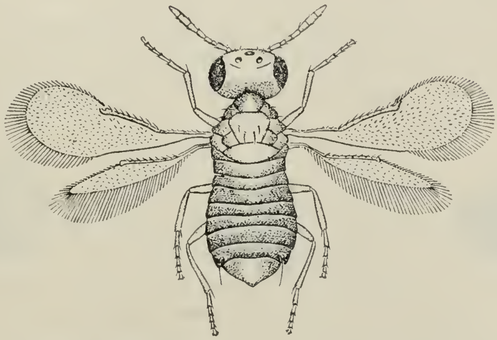

FIG. 27.—*Prospaltella* sp. Internal parasite from *Aspidiotus hederae* Vall.

The eggs of *R. lophanthæ* are often found beneath the red scale. Usually but one or two are found under the same scale. They are small oval shaped eggs white in color with a metallic iridescence. Upon hatching the larva makes its way from beneath the scale, consuming first the scale under which it is found, if it offers suitable food, and later attacks many different scales before reaching maturity. It eats out an irregular hole, rectangular usually, in the scale covering and most commonly just beyond the insect which is lying beneath.

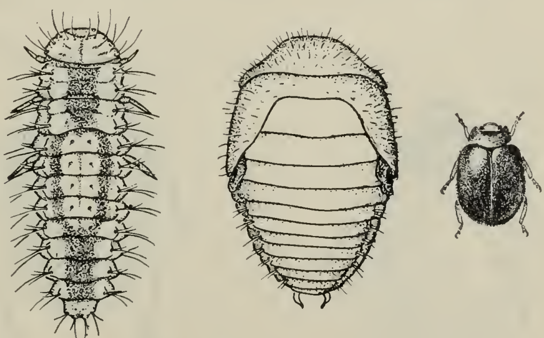

FIG. 28.—*Rhizobius lopanthae* Blaisd. Larva and pupa, x10; and adult, x5.

The mature larva is 4 mm. in length and about 1 mm. wide. The general color is dark gray with a lighter rectangular area on dorsal line of first four abdominal segments. There is also a strip similar in color on either side of the dorsal line on the meso- and meta-thoracic segments, also two narrower strips more laterally on last four abdominal segments.

There is a double row of conspicuous papillæ from each of which arise two or three hairs, the central papilla and hairs being longest. The hairs are light colored. There is a row of very small inconspicuous hairs, two on each segment, on either side of the dorsal line.

The adult is a small beetle, measuring 2 to 2½ mm. in length. The elytra are metallic black in color and covered with grayish or light brown hairs. The pro-thorax is brown with a faint darker band extending horizontally across the middle. Eyes black. Ventral surface and legs brown. This is sometimes called the "little brown neck beetle"

FIG. 29.—Some common ladybird beetles that feed on the Red Scale. x5.
1. Scymnus marginicollis, Mann.
2. Rhizobius lophanthæ, Blaisd.
3. Scymnus nebulosis, Lec.
4. Hippodamia convergens, Guer.
5. Coccinella californica, Mann.
6. Hippodamia ambigua, Lec.
7. Hippodamia ambigua, Lec.

because of the color of its pro-thorax, but others nearly similar in size and appearance might be confused with it.

Besides the red scale, this beetle is known to attack the yellow (*C. aurantii* var. *citrinus*) the oleander (*Aspidiotus hederæ*) the greedy (*A. rapax*) and the purple (*L. beckii*). It has been found commonly feeding on the purple scale, both in the vicinity of Los Angeles and San Diego. Its attacks on the purple appear to be limited more to the young or partly grown. The mature purple with its firm covering seems to be better protected from its attacks.

THE STEEL-BLUE LADYBIRD BEETLE.

Orchus chalybeus. Boisd.

This beetle is most abundant in Santa Barbara County. It is found well distributed over the citrus section of that county, and often occurs in large numbers. It is said to feed especially on the red and yellow scales. But it is not limited to those scales, and where it was seen most abundantly in Santa Barbara County it was associated with the black scale.

OTHER ENEMIES.

There are many other *Coccinellids* which may feed on the red scale occasionally, but these are still more general in their feeding than the two mentioned. Our commonest native species including *Hippodamia convergens, Coccinella californica, Chilocorus bivulnerus,* and others are all very general feeders and no one of them is particularly effective as a check on the scale. Aside from the *Coccinellidæ,* other enemies are certain species of the families *Chrysopidæ, Hemerobiidæ, and Reduviidæ,* and the predaceous mites.

THE YELLOW SCALE.

(*Chrysomphalus aurantii* var. *citrinus* Coq.)

This scale is very similar to the red (*C. aurantii*), and is classified as a variety having the varietal name *citrinus.* It is widely distributed over the citrus belt of southern California, often associated more or less with *aurantii.* But in addition to its occurrence in the southern part of the state it is also found on the citrus trees of the Sacramento Valley. There it is the most important scale occurring on citrus trees. In the same section the typical *aurantii* is not known. Why it doesn't occur there is not satisfactorily accounted for. In the interchange of nursery stock *aurantii* has probably had abundant opportunity of becoming established in the section. In fact, it is more likely to have been introduced, because of its wider occurrence in the south than *citrinus.* But it is not altogether improbable that the variety has predominated and become established. Experiments are now under way with a view to determining the factors responsible for such a distribution.

In the citrus belt of the south the yellow occurs in various degrees of severity ranging from occasional scales scattered about on parts of the tree, to badly infested trees requiring treatment. In Santa Barbara County at the present time the yellow is more common than the red. In San Bernardino and Riverside counties the yellow ranks second in importance among the insects of citrus trees, the red holding first place. In Los Angeles, Orange and San Diego counties the yellow is not counted among the first three. In these counties, to be sure, its place may be pre-empted by the purple. In former years it is said to have occurred in great abundance in certain sections as San Gabriel in Los Angeles County.

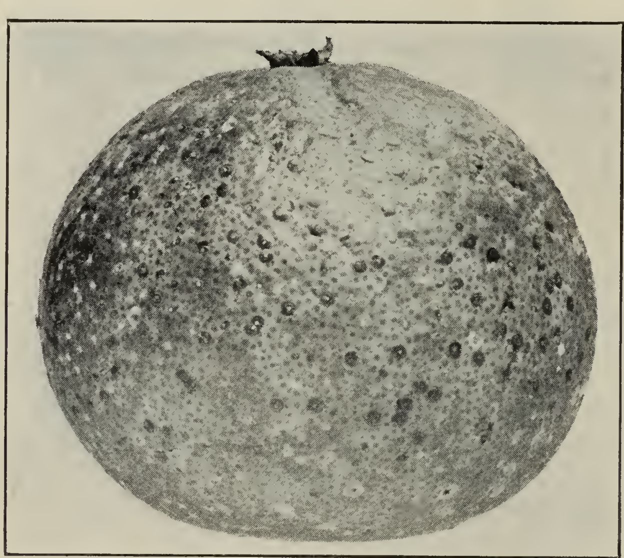

FIG. 30.—Yellow Scale, *chrysomphalus aurantii* var. *citrinus*, on orange.

Economic importance. While the yellow scale may frequently become abundant to the extent of injuring the tree, it can not be counted as serious as the red. This is partly because of its well known habit of avoiding the twigs and branches, and infesting largely the fruit and foliage. The yellow is found on the branches to some extent, but usually only in severe infestations, and even then only scattering. Trees have been seen where the leaves and fruit were completely covered with yellow scale for two or three years in succession, yet the tree itself was not seriously damaged. Of course, with such an infestation the tree is injured because of the injury to the leaves, and the fruit is rendered unfit for market. But, if a similar infestation had occurred with the red, a large portion of the tree would have been killed outright.

Another point that makes the yellow less to be feared in many sec-

FIG. 31.—Yellow Scale on orange leaf; upper surface.

FIG. 32.—Yellow Scale on under side of same leaf as shown in Fig. 33.

tions is its apparent lack of vigor, either of breeding or of becoming established rapidly. Exceptions may occur to this statement, as they do in the north and also in cases in the south. But it is not uncommon to find scattering infestations of yellow in a grove for years without becoming abundant enough to attract attention or make it worth while inaugurating control measures. Here is the opportune point to give credit to the parasites. But in those cases under consideration there were less parasites than on the red, and this maximum was only 10 per cent.

Differences between the red and yellow scales. Structurally there are no differences, thus far discovered in the insect itself, between the species *aurantii* and its variety *citrinus*. Exactly the same morphological characters occur in both, so that under the microscope it is not possible to be sure whether it is the red or yellow that is being examined. But the difference in appearance as they are found on the tree is usually not difficult to determine. The yellow is much lighter in color, is often less convex and often appears slightly larger in diameter. The additional fact that they are not found to any extent on the twigs, makes the field determination easy enough. But if only a few specimens are seen on a leaf, and these are not typically red or yellow, the determination is difficult and often impossible. This is particularly true of old, dead scales which in the case of the yellow become much darker in color and makes the similarity more complete.

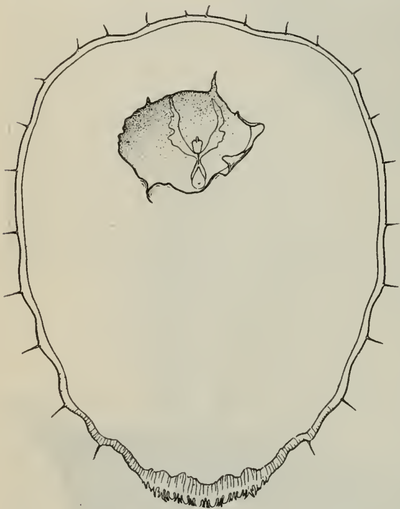

Fig. 33.—Yellow Scale showing exit hole of *Aspidiotiphagus citrinus*. Mouth parts of scale showing below in opening. x100.

The difference in color is not due to the insect itself so much as in the scale covering. When the insects are free from the scale covering, as between the molts, it is often very difficult to distinguish the red from the yellow, though before the same scales were lifted, the difference may have been evident enough. But during the molting periods the red is much darker in color than the yellow. Since the dorsal half of the cast skin is incorporated into the scale this difference persists in the scale covering. The color of the insects is most usually a light yellow, both with the red and yellow. But there is considerable variation, and the red is often apt to be distinctly darker in color, this being most marked, as intimated during the molting period or during the production of young.

Aside from the difference in habits of the two scales in attacking the twigs, there are other differences in habits. Where there are but a few scattering scales the yellow will be most likely to occur on the lower side of the leaves and usually too on those leaves near the lower part of the tree. In severe infestations also the lower side of the leaves are likely to have the greatest number of scales. Of course the red will often be found on the under side of the leaves as well as the upper, but the habit the yellow has sometimes of settling entirely on the lower side is not so true. The red is not averse to getting into the light and more open parts of the tree, while in many cases the yellow has the opposite habit. Where the occurrence of the yellow is severe, all parts of the tree may be attacked. But it can not be said that the yellow doesn't like heat, for it is most important in the warmest part of the southern citrus belt, and occurs exclusively in the large interior valleys of the north, where the summers are hotter than any part of the southern belt.

The life history of the yellow has been found to agree in all essential particulars with that of the red. The discussion of the seasonal history, locomotion, and spread also corresponds in both, so that these topics will not be again considered.

PARASITES.

Aspidiotiphagus citrinus Craw.

While the same parasite is likely to attack either the red or yellow, it being unlikely that it is able to distinguish the varietal differences, yet our acquaintance thus far with the following parasite has been largely in connection with the yellow. This is *Aspidiotiphagus citrinus* Craw, formerly known in this state as the "golden chalcid." It has been met with most commonly in Santa Barbara County. That it occurs here on the yellow may be accounted for because of the fact that the yellow is the commonest of the two scales in that county. However, some red were obtained in one of the localities where the yellow occurred, but we did not happen to secure any of the parasites from this material.

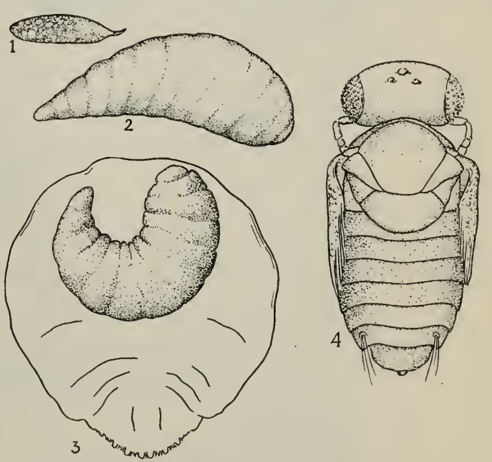

FIG. 34.—*Aspidiotiphagus citrinus.* 1 Egg. x175. 2 Larva. x30. 3 Yellow Scale harboring larva. 4 Pupa. x65.

This parasite was only rarely obtained during the past three years from either red or yellow scale material obtained from about Whittier, Los

Angeles, Pomona, Redlands, Riverside, Santa Ana, and San Diego. It was found more abundantly at Marysville, Oroville, Chico, Sacramento and Santa Barbara. Indeed, in the Sacramento Valley section is where the heaviest parasitization has been noted. Counts on a large number of scales from that section showed the percentage of parasitization to run as high as 67.

Aspidiotiphagus citrinus has been taken rather abundantly from purple scale in certain sections, especially where fumigation has not been regularly practiced. It, therefore, attacks the purple scale readily, and is not limited solely to the yellow as is supposed by some.

The egg of *A. citrinus* is oval in general shape, but distinctly flattened on one side. There is a minute stalk at one end and the egg is slightly more tapering at this end; color transparent, granular; length .08 mm., width .007 mm. The egg is found within the body of the scale. The one described was deposited at 5 P. M. December 30, 1910, and was dissected from the scale and examined on January 3, 1911.

The mature larva is glassy white in color; length .85 mm. long and .35 mm. broad at widest part, which is about the middle. It is thus much more elongate than that of *diaspidis*. The segments are very indistinct. While the middle is slightly widest, the head end is broad, but there is a gradual tapering to a narrow point at the posterior end. The mouth opening is in the center of the disc-shaped anterior segment. The mandibles are much narrower at the base than those of *diaspidis*. This character, together with the difference in the general shape, will readily distinguish the two larvæ. The larva of *Aspidiotiphagus citrinus* lives strictly within the body of the insect itself.

FIG. 35.—*Aspidiotiphagus citrinus* Craw. x40. Parasite of Yellow and Red Scales.

The pupa. Length .6 mm., width .28 mm. The general color upon first changing from the larva is white or whitish yellow, but it later turns very much darker. The head is light gray and thorax and abdomen almost black, with the abdominal segments lighter in color at the margins, giving a horizontal striped effect. The eyes and ocelli are red or reddish brown.

The adult. General color yellowish black. Head dull yellow, ocelli red, eyes black. Thorax dark yellow, with darker areas about bases of wings. Abdomen black, lighter at tip. Legs pale colored. Antennæ

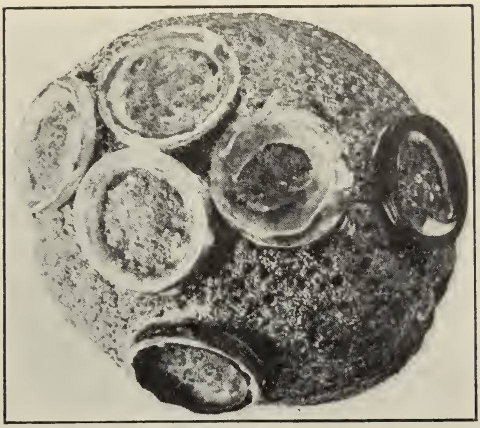

FIG. 36.—Fruit showing cells for rearing parasites.

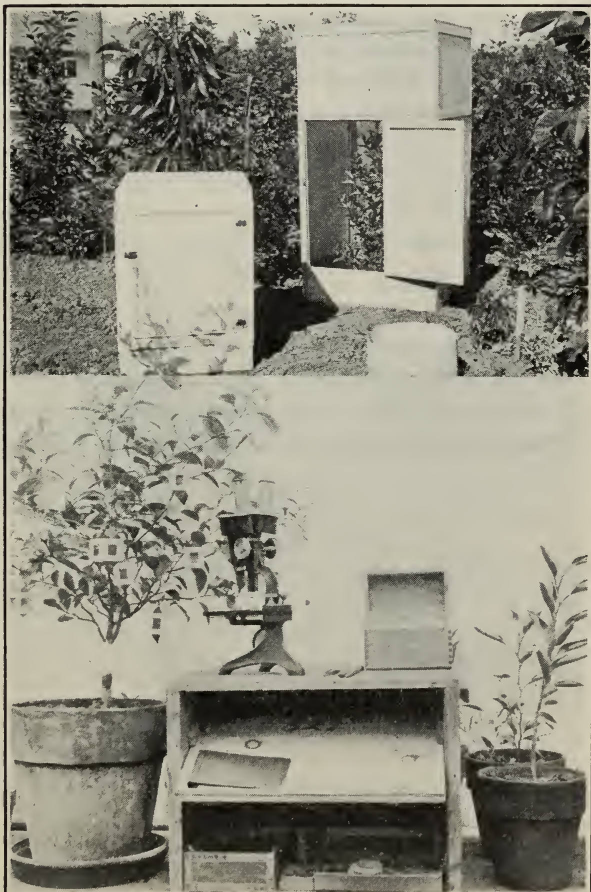

FIG. 37.—Above, cages enclosing small orange trees for studying parasites. Below, method of keeping accurate records on life history of scales.

8-jointed, comparative lengths as follows: 5, 25, 10, 8, 7, 10, 13, 18. Wings narrow, with a very long fringe; basal half dusky.

Life history work carried on with this parasite during the winter months indicates that 67 or 68 days are necessary for the complete life cycle. Adults placed in cells on fruit infested with scale were seen to oviposit in the scales on January 6th, and four adults issued on March 14th and 15th. This period being the coldest and wettest of the season must account for the slow development. During September the life cycle has been determined to occur in thirty days. The scales attacked, whether they be yellow or purple, are, with a few exceptions, always in the second stage, that is between the first and second molts.

SYSTEMATIC POSITION OF CHRYSOMPHALUS AURANTII MASK.

The family *Coccidæ,* which includes the scale insects, is divided into six sub-families. The red scale belongs to the sub-family *Diaspinæ,* which includes all those scales having flattened chitinous lobes at the posterior end of the body forming the pygidium. The genus *Chrysomphalus* is distinguished by having three distinct pairs of these lobes. There are in California but three species and one variety coming within this genus. The species *aonidium* is separated from the others by having four groups of spinnerets. The others have no groups of spinnerets. In the species *tenebricosus* the plates are scarcely branched, while in the species *aurantii* and the variety *citrinus* the plates are strongly branched.

C. aonidum, formerly known as *ficus,* is known as the Florida red scale. It is not, however, as serious a pest there as our red scale here. It is especially likely to infest plants in conservatories or under glass. Its occurrence in this state is based on an infestation of palms in a greenhouse.

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